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SENSITIVITY ANALYSIS OF SELECTED DIVOPS INPUT FACTORS

DECEMBER 1977

PREPARED BY

METHODOLOGY, RESOURCE AND COMPUTATION DIRECTORATE

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A fractional factorial experimental design is presented for a seven factor experiment with each factor having three levels. The design, ~~a (1/9) x 3~~ required 243 DIVOPS model runs and permitted the testing of all main effects and all two-factor interactions. A computer simulation experiment was conducted according to the design using the DIVOPS model. The seven input factors investigated are (1) WAIT, (2) PC/PCINT, (3) DELTHR, (4) SENDLA, (5) SENS, (6) TYPE, and (7) DENTI. Analyses of variance results are presented for seven output variables: (1) Total Number of Red Targets Detected, (2) Number of Red Personnel Killed Due to (cont)

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SUMMARY

1. The Target Acquisition Systems Force Mix Evaluation Analysis (TASFMEA) Study is sponsored by the Deputy Director, Combat Support Systems, Office of the Deputy Chief of Staff for Research, Development and Acquisition, Department of the Army. The TASFMEA Study consists of two phases. Phase I is the development of a methodology that will evaluate the cost and combat effectiveness of mixes of systems within a functional area. Phase II is a demonstration of the usefulness of the methodology. The methodology requires a division combat simulation whose combat outcome is sensitive to changes in the quality and quantity of sensor systems deployed.

2. The Division Operations (DIVOPS) Model is the primary candidate for the combat simulation. The purpose of the sensitivity experiment is to assess the capability of the DIVOPS Model to contribute to the evaluation of combat effectiveness of mixes of target acquisition systems. The objective of the DIVOPS sensitivity experiment is to identify those input factors reflecting the quality, quantity, and mix of sensor types which have a significant influence upon selected output variables.

3. The designed fractional factorial experiment is presented for a seven-factor experiment with each factor having three levels.

a. The design, a $(1/9) \times 3^7$, required 243 DIVOPS Model runs and permitted the testing of all main effects and all two-factor interactions. Analyses of variance are presented for seven output variables--also referred to as measures of effectiveness (MOE): MOE 1 - Total Number of Red Targets Detected; MOE 2 - Number of Red Personnel Killed Due to Detection; MOE 3 - Number of Red Weapons Killed Due to Detection; MOE 4 - Total Number of Red Personnel Killed; MOE 5 - Total Number of Red Weapons Killed; MOE 6 - Total Number of Blue Personnel Killed; and MOE 7 - Total Number of Blue Weapons Killed.

b. Analyses results illustrate the sensitivity of the seven input factors which are:

WAIT - Time a target acquisition (sensor) system uses waiting for and adjusting fire support,

PC/PCINT - Fraction of targets for which a sensor has coverage and line-of-sight,

DELTHR - Macro time clock increment,

SENDLA - Time required for a sensor system to process and report a detected target,

SENS - Total number of sensors,

TYPE - Operational classification defined by a combination of active/passive, mobile/stationary, targeting/non-targeting, and waiting/non-waiting,

DENTI - Inverse of the mean time to detect a target, given that the sensor has coverage and line-of-sight.

4. The seven DIVOPS Model output variables investigated are sensitive to the seven input factors. The input factor WAIT had the least effect upon the output variables. DELTHR and WAIT do not in general interact with the other input factors. However, PC/PCINT, SENDLA, SENS, TYPE, and DENTI do interact strongly. Variability in the Total Number of Red Personnel Killed and the Total Number of Red Weapons Killed is attributable to the variability in the Number of Red Personnel Killed Due to Detection and the Number of Red Weapons Killed Due to Detection, respectively. The Number of Red Weapons Killed Due to Detection and the Total Number of Red Weapons Killed are more sensitive to changes in SENDLA and WAIT than are the Number of Red Personnel Killed Due to Detection and the Total Number of Red Personnel Killed. Neither Red nor Blue Personnel or Weapons Killed can be predicted from the Total Number of Red Targets Detected. The DIVOPS Model reflects the effects of saturation of both sensors and fire support systems.

5. Analyses results successfully accomplished the experimental objectives by identifying the model input factors which significantly influence selected model output variables.

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SENSITIVITY ANALYSIS OF SELECTED DIVOPS INPUT FACTORS

CHAPTER 1
INTRODUCTION

1-1. BACKGROUND. The Target Acquisition Systems Force Mix Evaluation Analysis (TASFMEA) Study is sponsored by the Deputy Director, Combat Support Systems, Office of the Deputy Chief of Staff for Research, Development and Acquisition, Department of the Army. A tasking directive was issued by the study sponsor on 30 March 1977.

a. The TASFMEA Study consists of two phases. Phase I is the development of a methodology that will evaluate the cost and combat effectiveness of mixes of systems within a functional area. The methodology is to include the application of appropriate analytical techniques to determine the relative value to a combat force of individual components and alternative mixes. Phase II is a demonstration of the usefulness of the methodology. The demonstration is to determine a mix of target acquisition systems that yields an improved capability at a lesser cost while staying within currently planned target acquisition dollar and manpower resources.

b. The methodology for TASFMEA is described in the study plan, Reference 1. This methodology requires a division combat simulation whose combat outcome is sensitive to changes in the quality and quantity of sensor systems deployed.

c. The DIVOPS Model is the primary candidate for the combat simulation. DIVOPS is a two-sided, deterministic, nonplayer model of division-level ground combat with air support. The model produces a time history of results of combat, weapon and personnel losses, force locations, ammunition consumption, etc., over each time period and cumulative over the total time. Detailed documentation of DIVOPS is in Reference 2.

1-2. PURPOSE. The purpose of the DIVOPS sensitivity experiment was to assess the capability of the DIVOPS Model to evaluate the combat effectiveness of mixes of target acquisition systems.

1-3. OBJECTIVE. The objective of the DIVOPS sensitivity experiment was to identify those input factors reflecting the quality, quantity, and mix of sensor types which have a significant influence upon selected output variables and to estimate the magnitude of the input factor effects. The objective was the driving force in the selection of the input factors to be evaluated.

1-4. INPUT FACTOR SELECTION. In selecting the DIVOPS input factors, the primary candidates were those factors which describe sensor systems. The seven input factors selected are listed and described below (see Reference 2 for detailed definitions of the input factors).

a. WAIT. The amount of time, in minutes, that a waiting type sensor spends waiting for and adjusting artillery fire or close air support. By selecting zero as one of the levels of WAIT to be tested, the effect of a non-waiting sensor can be examined.

b. PC/PCINT. The fraction of target elements in each range band* and inter-FEBA interval** for which the sensor has both coverage and line-of-sight. Both variables are a function of sensor and target type. PC contains the data for the range bands and PCINT contains the data for the inter-FEBA interval. The values used for the sensitivity test were the same for all range bands and all target types.

c. DELTHR. The time, in minutes, of one increment of the macro time clock in DIVOPS. During each increment, activities and time support allocations are assigned and force locations updated. Ammunition inventories and weapons and personnel levels are changed to account for attrition and expenditure. DELTHR does not describe sensor characteristics, but was included in the experiment in order to assess its interaction with the other factors.

d. SENDLA. The time, in minutes, that a sensor spends processing and reporting a target it has detected.

e. SENS. The total number of sensors used for the model run.

f. TYPE. The DIVOPS Model classifies sensors according to one of the possible combinations of the following binary descriptors: active/passive, mobile/stationary, targeting/non-targeting, waiting/non-waiting. Two sensor types were used for the sensitivity test: an active/mobile/targeting/waiting sensor and an active/stationary/targeting/waiting sensor. The only impact a non-targeting sensor has on the model is to produce detections. The current tactical decision rules use sensor information only in the allocation of support fire or air strikes.

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*Distance on each side of the FEBA is divided into discrete bands.

**Distance between the Red and Blue FEBA.

g. DENTI. The inverse of the mean time to detect a target element, given that the sensor has coverage and line of sight. DENTI is a function of the sensor, target type and range band. For the sensitivity test the same value of DENTI was used for all target types and range bands.

1-5. MEASURES OF EFFECTIVENESS. Seven measures of effectiveness (MOE) were chosen to determine if battle outcome is sensitive to changes in the input factors. The first MOE selected was the total number of detections. It was included in order to establish basic trends and for correlation with the other MOE. The next two MOE chosen were Red personnel and Red weapons killed as a result of being detected. These were selected because the methodology for TASFMEA requires that the effectiveness model used be able to attribute damage directly to sensors; that is, give credit for kills to the sensor which detected the target engaged by artilley or air strikes. The remaining four MOE were selected to determine if gross battle outcome was effected by changes in the input factors. These four MOE are the total number of Red and Blue personnel and Red and Blue weapons killed.

1-6. SCENARIO. For the sensitivity experiment, 24 hours of combat were simulated, using forces and terrain as defined in the European I, Sequence 2A, Scenario Oriented Recurring Evaluation System (SCORES). The 3d Armored Division comprises the Blue covering and main battle forces.

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CHAPTER 2

EXPERIMENTAL DESIGN

2-1. DESIGN OF THE SENSITIVITY EXPERIMENT. The seven-factor, three-level factorial experiment ultimately designed for the sensitivity experiment is discussed in this chapter. First, the input factors and levels are given; then the fractional factorial design is explained. Finally, the analysis of variance (ANOVA) model is given, significance testing is discussed, and the ANOVA table is illustrated.

2-2. INPUT FACTORS. Seven input factors were selected for the sensitivity investigation. Because it was desired to investigate curvilinear trend effects, at least three levels of each input factor were required. The three levels ultimately developed for each of the seven factors are given in Table 2-1. The table also defines the units of measure of each factor.

Table 2-1. Factors and Levels Identification

Symbol	Factor	Levels		
		0	1	2
A	WAIT (minutes)	0.00	3.00	6.00
B	PC/PCINT (probability)	0.01	0.40	0.80
C	DELTHR (minutes)	7.50	11.25	15.00
D	SENDLA (minutes)	0.00	7.50	15.00
E	SENS (no. of sensors)	2.00	20.00	40.00
F	TYPE (percent stationary)	0.00	50.00	100.00
G	DENTI (1/minutes)	0.000006	1.50	3.00

2-3. DESIGN. a. The letter designators (A, B, ..., G) are later used as symbols for the seven factors. Similarly, the coded levels (0, 1, 2) for each factor are used later to specify the cell identification of the experimental design. The seven factors are completely crossed. That is, the three levels of each factor

appear in combination with all three levels of all the other factors. When all factors are completely crossed, the design is referred to as a factorial design. A full factorial design of the seven factors consists of $3^7 = 2187$ factor level combinations. However, all combinations are not necessary for the measuring and testing of all main effects and all two-factor interaction effects. Because no a priori information existed concerning the interaction effect of model input factors, it was deemed essential that the experimental design permits the estimation of main effects and two-factor interaction effects.

b. A fractional factorial design was developed using I = ABCDE = $CD^2EF^2G^2$ as the defining contrast, where A, B, ..., G represent the seven factors identified in Table 2-1. This yielded a $1/9 \times 3^7$ fractional factorial design having 243 design points. The design permits the estimation and testing of the 7 main effects and the $\binom{7}{2} = 21$ two-factor interaction effects. Aliases of the main effects and the two-factor interactions are given in Table 2-2. The 243 factor level combinations are identified in Table 2-3. The coded levels (0, 1, 2) are defined in Table 2-1. For example the fifth run, 2000101, denotes that each of the seven input factors be set at the input values--WAIT = 6.0, PC/PCINT = 0.01, DELTHR = 7.5, SENDLA = 0.0, SENS = 20.0, TYPE = 0.0, and DENTI = 1.5.

2-4. ANALYSIS OF VARIANCE (ANOVA). a. The fixed effects ANOVA model for the above fractional factorial design is:

$$y = u + A + B + \ldots + G + AB + AC + \ldots + EG + FG + R$$

The dependent variable (y) represents the measure of effectiveness (MOE) and the letters A, B, ..., G represent the input factor effects. The overall common effect is denoted by u, and the residual is denoted by R. Subscripts are omitted from the model equation for notational simplification. First, a fixed effects ANOVA is performed as illustrated in Table 2-4.

b. The test statistics for testing the significance of the model input factors are the ratios of mean squares in the F-ratio column. The test statistics are F distributed. Therefore, testing is performed by comparing each F-ratio to a critical F-value. For example, if (MS(A)/MS(R)) is equal to or greater than $F(1-\alpha, 2, 144)$, input factor A is statistically significant at the α-level of significance. That is, the change from 0 to 3 minutes and then from 3 to 6 minutes for the input factor WAIT causes a statistically significant effect upon the particular MOE under analysis. Similarly if $(MS(AB)/MS(R)) \geq F(1-\alpha, 4, 144)$, the input factors A and B are said to have a statistically significant interaction

effect upon the DIVOPS output MOE. Interactions are important because, if two input factors interact, conclusions about either of the factors are dependent upon the level of the other factor. The results of the testing will identify the statistically significant main effects and interactions. Results of analyses are presented in Chapter 3.

Table 2-2. Aliases (page 1 of 2 pages)

Effect	$ABCDE$	$CD^2EF^2G^2$	$ABC^2E^2F^2G^2$	ABD^2FG	$A^2B^2C^2D^2E^2$	C^2DE^2FG	A^2B^2CEFG	$A^2B^2DF^2G^2$
A	$AB^2C^2D^2E^2$	$ACD^2EF^2G^2$	AB^2CEFG	$AB^2DF^2G^2$	$BCDE$	AC^2DE^2FG	$BC^2E^2F^2G^2$	BD^2FG
B	AB^2CDE	$BCD^2DF^2G^2$	$AB^2C^2E^2F^2G^2$	AB^2D^2FG	$ACDE$	BC^2DE^2FG	[illegible] $E^2F^2G^2$	A^2DFG
C	ABC^2DE	CDE^2FG	$ABE^2F^2G^2$	$ABCD^2FG$	$ABDE$	DE^2FG	$BCE^2F^2G^2$	$ABCD^2FG$
D	$ABCD^2E$	CEF^2G^2	$ABC^2DE^2F^2G^2$	$ABFG$	$ABCE$	$CDEF^2G^2$	$ABC^2D^2E^2F^2G^2$	$ABDFG$
E	$ABCDE^2$	$CD^2E^2F^2G^2$	$ABC^2F^2G^2$	ABD^2EFG	$ABCD$	$CD^2F^2G^2$	$ABC^2EF^2G^2$	ABD^2E^2FG
F	$ABCDEF$	CD^2EG^2	$ABC^2E^2G^2$	ABD^2F^2G	$A^2B^2C^2D^2E^2F$	$C^2DE^2F^2G$	$A^2B^2CEF^2G$	$A^2B^2DG^2$
G	$ABCDEG$	CD^2EF^2	$ABC^2E^2F^2$	ABD^2FG^2	$A^2B^2C^2D^2E^2G$	$C^2DE^2FG^2$	$A^2B^2CEFG^2$	$A^2B^2DF^2$
AB	$ABC^2D^2E^2$	$ABCD^2EF^2G^2$	$ABCEFG$	$ABDF^2G^2$	CDE	ABC^2DE^2FG	$CEFG$	DF^2G^2
AB^2	$AC^2D^2E^2$	$AB^2CD^2EF^2G^2$	$ACEFG$	$ABDF^2G^2$	$BC^2D^2E^2$	$AB^2C^2DE^2FG$	$BCEFG$	BDF^2G^2
AC	$AB^2CD^2E^2$	$AC^2D^2EF^2G^2$	AB^2EFG	$AB^2C^2DF^2G^2$	BDE	ADE^2FG	$BCE^2F^2G^2$	BC^2D^2FG
AC^2	AB^2D^2E	$AC^2D^2EF^2G^2$	AB^2C^2EFG	$AB^2CDF^2G^2$	$BCDE$	$ACDE^2FG$	$BD^2E^2F^2G^2$	BCD^2FG
AD	$AB^2C^2DE^2$	AEF^2G^2	AB^2CD^2EFG	$AB^2F^2G^2$	BCE	$AC^2D^2E^2FG$	$BC^2D^2E^2F^2G^2$	$BDFG$
AD^2	$AB^2C^2E^2$	$ACEF^2G^2$	AB^2CDEFG	$AB^2D^2F^2G^2$	BCD^2E	AC^2DE^2FG	$BC^2DE^2F^2G^2$	BFG
AE	$AB^2C^2D^2E$	$ACD^2E^2F^2G^2$	AB^2CFG	$AB^2DE^2F^2G^2$	BCD	AC^2DFG	$BC^2EF^2G^2$	BD^2E^2FG
AE^2	$AB^2C^2F^2$	$ACD^2F^2G^2$	AB^2CE^2FG	AB^2DFG^2	$BCDE^2$	AC^2DEFG	$BC^2F^2G^2$	BD^2EFG
AF	$AB^2C^2D^2E^2F^2$	ACD^2EG^2	AB^2CEG	$AB^2D^2FG^2$	$BCDEF^2$	$AC^2DE^2F^2G$	BC^2E^2FG	BD^2G
AF^2	$AB^2C^2D^2E^2F$	$ACD^2EF^2G^2$	AB^2CEF^2G	AB^2DG^2	$BCDEF$	AC^2DE^2G	BC^2E^2G	BD^2F^2G
AG	$AB^2C^2D^2E^2G^2$	ACD^2EF^2	AB^2CEF	AB^2DF^2G	$BCDEG$	$AC^2DE^2FG^2$	$BC^2E^2F^2G$	BD^2F
AG^2	$AB^2C^2D^2E^2G$	ACD^2EF^2	AB^2CEFG^2	$AB^2DF^2G^2$	$BCDEG$	AC^2DE^2F	$BC^2E^2F^2G^2$	$BDFG^2$
BC	AB^2C^2DE	$BC^2D^2EF^2G^2$	$AB^2E^2F^2G^2$	AB^2CD^2FG	ADE	BDE^2FG	$ACE^2F^2G^2$	AC^2D^2FG
BC^2	AB^2DE	$BD^2EF^2G^2$	$AB^2CE^2F^2G^2$	$AB^2C^2D^2FG$	AC^2DE	$BCDE^2FG$	$AE^2F^2G^2$	ACD^2FG
BD	AB^2CD^2E	$BCDF^2G^2$	$AB^2C^2DE^2F^2G$	AB^2FG	ACE	$BC^2D^2E^2FG$	$AC^2D^2E^2F^2G^2$	AB^2DFG
BD^2	AB^2CE	$BCDEF^2G^2$	$AB^2C^2D^2E^2F^2G^2$	AB^2DFG	ACD^2E	BC^2E^2FG	$AC^2DE^2F^2G^2$	AFG
BE	AB^2CDE^2	$BCD^2E^2F^2G^2$	$AB^2C^2F^2G^2$	AB^2D^2EFG	ACD	BC^2DFG	$AC^2EF^2G^2$	AD^2E^2FG
BE^2	AB^2CD	$BCD^2F^2G^2$	$AB^2C^2EF^2G^2$	$AB^2D^2E^2FG$	$ACDE^2$	BC^2DEFG	$AC^2F^2G^2$	AD^2EFG

Table 2-2. Aliases
(page 2 of 2 pages)

Effect	A B C D E	$C D^2E F^2G^2$	$A B C^2E^2F^2G^2$	$A B D^2F E$	$A^2B^2C^2D^2E^2$	$C^2D E^2F G$	$A^2B^2C E F G$	$A^2B^2D F^2G^2$
BF	$A B^2C D E F$	$B C D^2E G^2$	$A B^2C^2E^2G^2$	$A B^2D^2F^2G$	$A C D E F^2$	$B C^2D E^2F^2G$	$A C^2E^2F G^2$	$A D^2G$
BF^2	$A B^2C D E F^2$	$B C D^2E F G^2$	$A B^2C^2E^2F G^2$	$A B^2D^2G$	A C D E F	$B C^2D E^2G$	$A C^2E^2G^2$	$A D^2F^2G$
BG	$A B^2 C D E G$	$B C D^2F F^2$	$A B^2C^2E^2F^2$	$A B^2D^2F G^2$	$A C D E G^2$	$B C^2D E^2F G^2$	$A C^2E^2F^2G$	$A D^2F^2$
BG^2	$A B^2C D E G^2$	$B C D^2E F^2G$	$A B D E^2F^2G^2$	A B C F G	A C D E G	$B C^2D E^2F$	$A C^2E^2F^2$	$A D^2F G^2$
CD	$A B C^2D^2E$	$C E^2F G$	$A B D E^2F^2G^2$	A B C F G	A B E	$D E F^2G^2$	$A B C D^2E^2F^2G^2$	$A B C^2D F G$
CD^2	$A B C^2E$	$C D^2E^2F G$	$A B D^2E^2F^2G^2$	A B C D F G	$A B D^2E$	$E F^2G^2$	$A B C D E^2F^2G^2$	$A B C^2F G$
CE	$A B C^2D E^2$	C D E F G	$A D F^2G^2$	$A B C D^2E F G$	A B D	D F G	$A B C E F^2G^2$	$A B C^2D^2E^2F G$
CE^2	$A B C^2D$	C D F G	$A B E F^2G^2$	$A B C D^2E^2F G$	$A B D E^2$	D E F G	$A B C E F^2G^2$	$A B C^2D^2E F G$
CF	$A B C^2D E F$	$C D F^2G$	$A B E^2G^2$	$A B C D^2F^2G$	$A B D E F^2$	$D E^2F^2G$	$A B C E^2F G^2$	$A B C^2D^2F G$
CF^2	$A B C^2D E F^2$	$C D E^2F^2G$	$A B E^2F G^2$	$A B C D^2G$	A B D E F	$D E^2G$	$A B C E^2G^2$	$A B C^2D^2F^2G^2$
CG	$A B C^2D E G$	$C D E^2F G$	$A B E^2F^2$	$A B C D^2F G^2$	$A B D E G^2$	$D E^2F G$	$A B C E^2F^2G$	$A B C^2D^2F$
CG^2	$A B C^2D E G^2$	$C D E^2F G^2$	$A B E^2F^2G$	$A B C D^2F$	A B D E G	$D E^2F$	$A B C E^2F^2$	$A B C^2D^2F G^2$
DE	$A B C D^2E^2$	$C E^2F^2G^2$	$A B C^2D F^2G^2$	A B E F G	A B C	$C D F^2G^2$	$A B C^2D^2E F^2G^2$	$A B D E^2F G$
DE^2	$A B C D^2$	$C F^2G^2$	$A B C^2D E F^2G^2$	$A B E^2F G$	$A B C E^2$	$C D E^2F^2G^2$	$A B C^2D^2F^2G^2$	A B D E F G
DF	$A B C D^2E F$	$C E G^2$	$A B C^2D E^2G^2$	$A B F^2G$	$A B C E F^2$	$C D E F G^2$	$A B C^2D^2F^2F G^2$	A B D G
DF^2	$A B C D^2E F^2$	$C E F G^2$	$A B C^2D E^2F G^2$	A B G	A B C E F	$C D E G^2$	$A B C^2D^2E^2G^2$	$A B D F^2G$
DG	$A B C D^2E G$	$C E F^2G$	$A B C^2D E^2F^2$	$A B F G^2$	$A B C E G^2$	$C D E F^2G$	$A B C^2D^2E^2F^2G$	A B D F
DG^2	$A B C D^2E G^2$	$C E F^2G$	$A B C^2D E^2F^2G^2$	$A B F^2$	A B C E G	$C D E F^2$	$A B C^2D^2E^2F^2$	$A B D F G^2$
EF	$A B C D E^2F$	$C D^2E^2G^2$	$A B C^2G^2$	$A B D^2E F G$	$A B C D F^2$	$C D^2F G^2$	$A B C^2E F G^2$	$A B D^2E^2G$
EF^2	$A B C D E^2F^2$	$C D^2E^2F G$	$A B C^2F G^2$	$A B D^2E G$	A B C D F	$C D^2G^2$	$A B C^2E G^2$	$A B D^2E^2F^2G$
EG	$A B C D E^2G$	$C D^2E^2F^2$	$A B C^2F^2$	$A B D^2E F G^2$	$A B C D G^2$	$C D^2F^2G$	$A B C^2E F^2G$	$A B D^2E^2F$
EG^2	$A B C D E^2G^2$	$C D^2E^2F^2G$	$A B C^2F^2G$	$A B D^2E F$	A B C D G	$C D^2F^2$	$A B C^2E F^2$	$A B D^2E^2F G^2$
FG	A B C D E F G	$C D^2E$	A B C E	$A B D F^2G^2$	$A B C D E F^2G^2$	$C D^2E F G$	$A B C^2E^2F G$	$A B D^2$
FG^2	$A B C D E F G^2$	$C D^2E G$	$A B C^2E^2G$	$A B D^2F^2$	$A B C D E F^2G$	$C D^2F F$	$A B C^2E F$	$A B D^2G^2$

Table 2-3. DIVOPS Sensitivity Experiment Runs
(page 1 of 2 pages)

Run no.	Factor levels	Run no.	Factor levels	Run no.	Factor levels	Run no.	Factor levels
	ABCDEFG		ABCDEFG		ABCDEFG		ABCDEFG
001	0000000	042	0011122	083	2100021	124	1111220
002	0000021	043	2011220	084	2100012	125	1111211
003	0000012	044	2011211	085	1100110	126	1111202
004	2000110	045	2011202	086	1100101	127	2112020
005	2000101	046	0012020	087	1100122	128	2112011
006	2000122	047	0012011	088	0100220	129	2112002
007	1000220	048	0012002	089	0100211	130	1112100
008	1000211	049	2012100	090	0100202	131	1112121
009	1000202	050	2012121	091	1101020	132	1112112
010	2001020	051	2012112	092	1101011	133	0112210
011	2001011	052	1012210	093	1101002	134	0112201
012	2001002	053	1012201	094	0101100	135	0112222
013	1001100	054	1012222	095	0101121	136	0120020
014	1001121	055	1020020	096	0101112	137	0120011
015	1001112	056	1020011	097	2101210	138	0120002
016	0001210	057	1020002	098	2101201	139	2120100
017	0001201	058	0020100	099	2101222	140	2120121
018	0001222	059	0020121	100	0102010	141	2120112
019	1002010	060	0020112	101	0102001	142	1120210
020	1002001	061	2020210	102	0102022	143	1120201
021	1002022	062	2020201	103	2102120	144	1120222
022	0002120	063	2020222	104	2102111	145	2121010
023	0002111	064	0021010	105	2102102	146	2121001
024	0002102	065	0021001	106	1102200	147	2121022
025	2002200	066	0021022	107	1102221	148	1121120
026	2002221	067	2021120	108	1102212	149	1121111
027	2002212	068	2021111	109	1110010	150	1121102
028	2010010	069	2021102	110	1110001	151	0121200
029	2010001	070	1021200	111	1110022	152	0121221
030	2010022	071	1021221	112	0110120	153	0121212
031	1010120	072	1021212	113	0110111	154	1122000
032	1010111	073	2022000	114	0110102	155	1122021
033	1010102	074	2022021	115	2110200	156	1122012
034	0010200	075	2022012	116	2110221	157	0122110
035	0010221	076	1022110	117	2110212	158	0122101
036	0010212	077	1022101	118	0111000	159	0122122
037	1011000	078	1022122	119	0111021	160	2122220
038	1011021	079	0022220	120	0111012	161	2122211
039	1011012	080	0022211	121	2111110	162	2122202
040	0011110	081	0022202	122	2111101	163	1200000
041	0011101	082	2100000	123	2111122	164	1200021

Table 2-3. DIVOPS Sensitivity Experiment Runs
(page 2 of 2 pages)

Run no.	Factor levels ABCDEFG	Run no.	Factor levels ABCDEFG	Run no.	Factor levels ABCDEFG	Run no.	Factor levels ABCDEFG
165	1200012	185	1202111	205	0211220	225	0220222
166	0200110	186	1202102	206	0211211	226	1221010
167	0200101	187	0202200	207	0211202	227	1221001
168	0200122	188	0202221	208	1212020	228	1221022
169	2200220	189	0202212	209	1212011	229	0221120
170	2200211	190	0210010	210	1212002	230	0221111
171	2200202	191	0210001	211	0212100	231	0221102
172	0201020	192	0210022	212	0212121	232	2221200
173	0201011	193	2210120	213	0212112	233	2221221
174	0201002	194	2210111	214	2212210	234	2221212
175	2201100	195	2210102	215	2212201	235	0222000
176	2201121	196	1210200	216	2212222	236	0222021
177	2201112	197	1210221	217	2220020	237	0222012
178	1201210	198	1210212	218	2220011	238	2222110
179	1201201	199	2211000	219	2220002	239	2222101
180	1201222	200	2211021	220	1220100	240	2222122
181	2202010	201	2211012	221	1220121	241	1222220
182	2202001	202	1211110	222	1220112	242	1222211
183	2202022	203	1211101	223	0220210	243	1222202
184	1202120	204	1211122	224	0220201		

Table 2-4. Analysis of Variance

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-ratio
A	2	SS(A)	MS(A)	MS(A)/MS(R)
B	2	SS(B)	MS(B)	MS(B)/MS(R)
C	2	SS(C)	MS(C)	MS(C)/MS(R)
D	2	SS(D)	MS(D)	MS(D)/MS(R)
E	2	SS(E)	MS(E)	MS(E)/MS(R)
F	2	SS(F)	MS(F)	MS(F)/MS(R)
G	2	SS(G)	MS(G)	MS(G)/MS(R)
AB	4	SS(AB)	MS(AB)	MS(AB)/MS(R)
AC	4	SS(AC)	MS(AC)	MS(AC)/MS(R)
AD	4	SS(AD)	MS(AD)	MS(AD)/MS(R)
AE	4	SS(AE)	MS(AE)	MS(AE)/MS(R)
AF	4	SS(AF)	MS(AF)	MS(AF)/MS(R)
AG	4	SS(AG)	MS(AG)	MS(AG)/MS(R)
BC	4	SS(BC)	MS(BC)	MS(BC)/MS(R)
BD	4	SS(BD)	MS(BD)	MS(BD)/MS(R)
BE	4	SS(BE)	MS(BE)	MS(BE)/MS(R)
BF	4	SS(BF)	MS(BF)	MS(BF)/MS(R)
BG	4	SS(BG)	MS(BG)	MS(BG)/MS(R)
CD	4	SS(CD)	MS(CD)	MS(CD)/MS(R)
CE	4	SS(CE)	MS(CE)	MS(CE)/MS(R)
CF	4	SS(CF)	MS(CF)	MS(CF)/MS(R)
CG	4	SS(CG)	MS(CG)	MS(CG)/MS(R)
DE	4	SS(DE)	MS(DE)	MS(DE)/MS(R)
DF	4	SS(DF)	MS(DF)	MS(DF)/MS(R)
DG	4	SS(DG)	MS(DG)	MS(DG)/MS(R)
EF	4	SS(EF)	MS(EF)	MS(EF)/MS(R)
EG	4	SS(EG)	MS(EG)	MS(EG)/MS(R)
FG	4	SS(FG)	MS(FG)	MS(FG)/MS(R)
R	144	SS(R)	MS(R)	
Total	242	SS(T)		

CHAPTER 3

SENSITIVITY ANALYSIS

3-1. ANALYSIS INTRODUCTION. This chapter presents the analysis results obtained from applying the methodology explained in the previous chapter. Analyses results are given for seven DIVOPS output variables, hereafter referred to as measures of effectiveness (MOE). The MOE are categorized into three groups: Detections, Personnel, and Weapons. Analyses are presented for each MOE group in turn.

3-2. MODEL OUTPUT. The seven MOE are listed in Table 3-1. The output data for each of the seven MOE are given in Table D-1 of Appendix D.

Table 3-1. Measures of Effectiveness

MOE	Definition
1	Total Number of Red Targets Detected
2	Number of Red Personnel Killed Due to Detection
3	Number of Red Weapons Killed Due to Detection
4	Total Number of Red Personnel Killed
5	Total Number of Red Weapons Killed
6	Total Number of Blue Personnel Killed
7	Total Number of Blue Weapons Killed

3-3. PRESENTATION ORDER. The analysis of variance illustrated in Table 2-4 was performed on each of the seven MOE. During the analyses and the study of analyses results, a commonality or pattern emerged. With hindsight certain MOE groupings are felt to be natural. Personnel Killed (MOE 2, 4, and 6) form one group, while Weapons Killed (MOE 3, 5, and 7) form another. Consequently, for the purpose of analyses discussion, the order of presentation is:

A. MOE 1 --------------- Detection

B. MOE 2, 4, and 6 ----- Personnel

C. MOE 3, 5, and 7 ----- Weapons.

3-4. PRESENTATION CONTENT. Because the ANOVA model is a fixed effects model, the null hypotheses being tested by the ANOVA are the equality of means and mean differences. For example, the F-ratio MS(A)/MS(R) tests the equality of the three WAIT factor means. The F-ratio MS(AB)/MS(R) tests the WAIT x PC/PCINT interaction, the equality of the mean differences of one factor (say WAIT) for each of the levels of the other factor (say PC/PCINT). Figure 3-1 is an illustration of no interaction between two factors; Figure 3-2 is an illustration of interaction between two factors. Note, the lines in Figure 3-1 are parallel, while the lines in Figure 3-2 are not parallel. That is, in Figure 3-1, the change in the MOE when WAIT is varied from 0 to 3 to 6 minutes is the same for each of the three PC/PCINT values. In Figure 3-2, the change in the MOE when WAIT is varied depends upon which value is used for the PC/PCINT factor. For completeness, all means tested by the analysis of variance are tabulated. First the marginal means are presented. Then the two-way means corresponding to the two-factor interactions are given. Following the ANOVA table, a plot of the marginal means is given. Finally, plots of some of the most significant interactions are shown.

3-5. DETECTION MOE. a. <u>Main Effects</u>. The marginal means for MOE 1, Total Number of Red Targets Detected, are tabulated in Table E-1 of Appendix E. The two-way means are given in Table E-2. The conventional notation of using *, **, and *** to denote significant F-ratios for α -levels of significance of $\alpha = 0.05$, 0.01, and 0.001, respectively, are used in the ANOVA tables. (See the footnotes at the bottom of Table E-3.) An examination of the table shows that SENDLA (D) is the most highly significant main effect and that WAIT (A) and SENS (E) are not statistically significant at the 0.05-level of significance. DELTHR (C) is significant at only the 0.05-level of significance. The main effects are illustrated graphically in Figure E-1, which contain plots of the marginal means tabulated in Table E-1.

b. <u>Interaction Effects</u>. Further examination of the ANOVA table shows that four interactions are significant at the 0.001-level of significance, PC/PCINT x SENDLA (BD), SENDLA x TYPE (DF), SENDLA x DENTI (DG) and TYPE x DENTI (FG). Two of the interactions are illustrated pictorially in Figures E-2 and E-3. PC/PCINT x SENDLA (BD) is shown in Figure E-2, and SENDLA x DENTI (DG) is shown in Figure E-3.

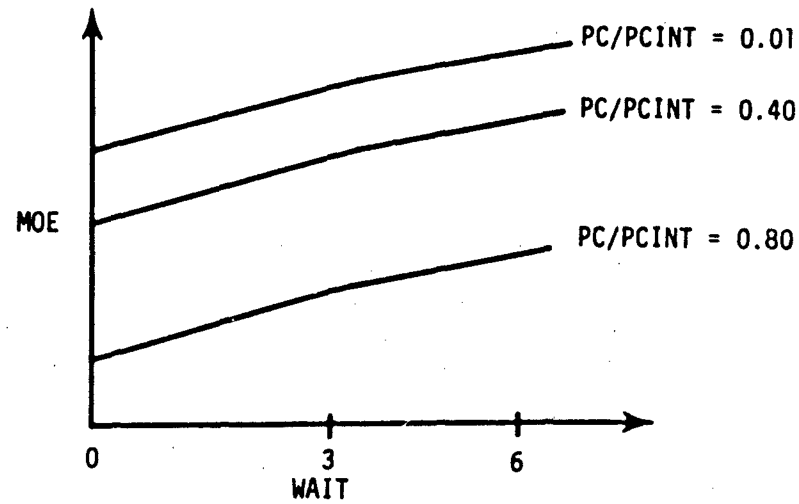

Figure 3-1. No Interaction

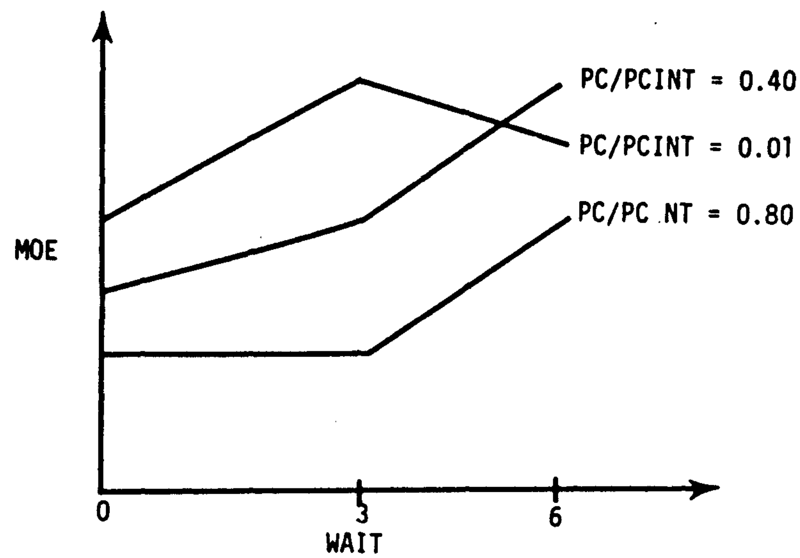

Figure 3-2. Interaction

Note in Figure E-2 how differently the change in the Total Number of Red Detections is when PC/PCINT (B) is at 0.01 and SENDLA (D) is varied than is the change when PC/PCINT (B) is at 0.4 or 0.8 and SENDLA (D) is varied. This illustrates a strong interaction effect which the two factors have upon the MOE.

c. Discussion. Two phenomena, the behavior of DENTI and SENDLA, deserve special mention. In Table E-1 and/or Figure E-1, note the large change in the number of detections when each factor changes from its low to mid value. Then a leveling off in the number of detections is observed when the factors change from mid to high values (See Figures E-1, E-2 and E-3). The effect of DENTI suggests a saturation phenomenon. That is, increasing DENTI (decreasing detection time) beyond a certain point does not produce an improvement in performance. The effect of SENDLA illustrates the criticality of delay in processing and reporting detections.

3-6. PERSONNEL MOE. a. Main Effects

(1) The marginal means for the three personnel MOE (2, 4, and 6) are tabulated in Table F-1 of Appendix F. The two-way means for the three MOE are given in Tables F-2, F-3, and F-4, respectively. Tables F-5, F-6, and F-7 contain the ANOVA tables for the three MOE. A cursory examination of Tables F-5 and F-6 shows that DENTI (G) is the most highly significant main effect, while WAIT (A) is the least significant. Referring back to Table F-1 shows that the maximum difference among the three means is for DENTI (1572 for MOE 2 and 1461 for MOE 4). Also, the minimum difference is for WAIT (279 for MOE 2 and 248 for MOE 4). Although the ANOVA table for MOE 6 (Table F-7) also shows DENTI to be significant at the α = 0.001-level of significance and WAIT to be nonsignificant at the α = 0.05-level of significance, the most highly significant factor is DELTHR (C).

(2) The marginal means tabulated in Table F-1 are plotted in Figures F-1, F-2, and F-3 of Appendix F. Figures F-1 and F-2 show the consistency of the influence of the seven input factors upon the two Red personnel MOE. This consistency is further borne out by the differences between MOE 2 and MOE 4 marginal means. Corresponding marginal means of MOE 2 were subtracted from MOE 4 and are tabulated in Table 3-2. All mean differences are relatively constant except those of the DELTHR factor. The average of the mean differences in Table 3-2 is 4,331. This constant difference is illustrated graphically in Figure F-4 in which each MOE is plotted on the same scale. Figure F-5 is also included for completeness. It shows the total Red and Blue personnel killed on the same graph. The figure shows that the input factors do not

influence Blue personnel in the exact opposite manner that they influence Red personnel. The plots for Blue personnel are not mirror images of the Red personnel plots.

Table 3-2. MOE 4 Marginal Means Minus MOE 2 Marginal Means

Factor	Level		
	0	1	2
A - WAIT	4,308	4,341	4,338
B - PC/PCINT	4,323	4,316	4,349
C - DELTHR	4,592	3,810	4,585
D - SENDLA	4,305	4,331	4,351
E - SENS	4,354	4,401	4,277
F - TYPE	4,300	4,335	4,353
G - DENTI	4,331	4,353	4,303

(3) The above are merely observations; they are not conclusions. Before statistical inferences can be made about the significance of the input factors, interaction effects must be investigated.

b. Interaction Effects

(1) The importance of interactions cannot be over emphasized. If two input factors interact, the influence of a change in an input value of one factor upon an MOE is dependent upon the input value at which the other factor is set. Consequently, input values of a particular input factor cannot be changed without considering the input value(s) used for the factor(s) which interact with the particular input factor.

(2) To examine the interaction effects, we return to the ANOVA tables (Tables F-5, F-6, and F-7). An examination of the ANOVA tables suggests a pattern. Factors WAIT (A) and DELTHR (C) do not interact with the other input factors. However, the other factors interact strongly upon the three MOE. Table 3-3 shows the

rank ordering of the statistical significances of the most highly significant interaction effects. The interaction between PC/PCINT and DENTI is the most significant interaction for MOE 2 and MOE 4, and the interaction between PC/PCINT and SENS is the most highly significant interaction for MOE 6.

Table 3-3. Rank Order of Interactions Significances for MOE 2, 4, and 6

Interaction	MOE 2	MOE 4	MOE 6
BG - PC/PCINT x DENTI	1	1	3
BE - PC/PCINT x SENS	2	2	1
BD - PC/PCINT x SENDLA	4	4	4
EG - SENS x DENTI	5	5	5
DG - SENDLA x DENTI	7	6	2
EF - SENS x TYPE	3	3	-
DF - SENDLA x TYPE	6	8	6
BF - PC/PCINT x TYPE	-	7	-

(3) Note the pair-wise interaction among the four factors, PC/PCINT, SENDLA, SENS, and DENTI (B, D, E, and G). A similar pattern will also be seen later for MOE 3, 5, and 7. Because of this pattern, B, D, E, and G were collapsed over the other three factors. This gave a full 3^4 design with 3 replications per cell. A four-factor ANOVA revealed none of the four three-factor interactions (BDE, BDG, BEG, and DEG) to be significant for any of the seven MOE. The five interactions involving B, D, E, and G (BG, BE, BD, EG, and DG) are shown graphically in Figures F-6 through F-10 in Appendix F. Figures F-11 through F-15 illustrate the same five interactions for MOE 4, and Figures F-16 through F-20 illustrate them for MOE 6.

(4) Although the three-factor interactions cited above were not statistically significant by the four-factor ANOVA, they were studied. The PC/PCINT x SENDLA x DENTI (BDG) means and the PC/PCINT x SENS x DENTI (BEG) means were extracted and are shown in Tables F-8, F-9, and F-10. In Tables F-8 and F-9, the smallest

mean is underlined and the largest mean is circled. In Table F-10, the smallest mean is circled and the largest mean is underlined. Consider the bottom table (BEG) of Table F-8 and note the locations of the maximum value. When SENS = 2, E(0), the maximum is at PC/PCINT = 0.40 and DENTI = 1.5, B(1) and G(1). However, when SENS = 20, E(1), the maximum moves to PC/PCINT = 0.01, B(0). Then, when SENS = 40, E(2), the maximum moves to DENTI = 3.0, G(2). The BEG three-way mean table is illustrated graphically in Figure F-21. The same interaction is illustrated for MOE 4 and MOE 6 in Figures F-22 and F-23, respectively.

c. Discussion

(1) The relationship between MOE 2 and MOE 4 is important for the TASFMEA methodology because only the characteristics and mixes of sensors will be changed. All the variability in MOE 4 is equal to and attributable to the variability in MOE 2. No gain or loss due to changes in the input factors is dampened nor amplified by synergistic effects in the model. Thus, all the changes in effectiveness will be directly attributable to the individual sensors.

(2) DELTHR is the exception to the above relationship. A close check of the model code revealed that some sections of the model, particularly those dealing with close air support, had been programed under the assumption that the value of DELTHR would always be 15 minutes. However, since DELTHR generally does not interact with the other factors, this does not influence the effects of the other factors.

(3) For all three personnel MOE, effectiveness decreased between the mid and high levels of DENTI. This also appears in the interactions between DENTI and SENS. Figures F-9 and F-14 show the interaction between DENTI and SENS for MOE 2 and 4, respectively. In both figures the peak level of Red losses is reached when DENTI is at the middle level and SENS is at the high level. This tendency is due to the effect of saturation of various model processes. Basically, the problem is too much information, too fast for the target selection process, the fire allocation process, and the target engagement process to handle optimally. When the sensors reach a point at which a large number of targets are detected, the target selection and fire allocation processes have more targets than engagement capabilities. This results in the higher priority targets only being engaged. Since these high priority targets are more difficult to kill than most targets, the effect is that lower priority Red targets are left unengaged. Thus, Red effectiveness is greater when only the higher priority targets are engaged than when Red targets are engaged in a more

uniform manner. This degradation is due in part to limitations in the ability of the target allocation routines to handle special cases. The threshold problem is compounded because the threshold is a complex function of several variables. Since it is desirable to simulate saturation, this is not necessarily a model weakness. However, in using the model, it must be realized that these thresholds exist and results must be monitored to insure that they occur at reasonable levels.

(4) The number of detections (MOE 1) increases, as it should, as PC/PCINT is increased. However, the trend for the personnel MOE as PC/PCINT is increased is counterintuitive. A review of the model code revealed no errors or reasons for this counterintuitive behavior. Since PC/PCINT interacts so strongly with the other variables, particularly DENTI, SENS, and SENDLA, a careful study of these interactions was made. A consistent pattern emerged, PC/PCINT interacting with DENTI, SENS, and SENDLA. As shown in Figure F-6, when the other factor (DENTI) is at its middle or high level, the trend of PC/PCINT is similar to the PC/PCINT main effect. However, when DENTI is at its low level the trend for PC/PCINT is similar to the DENTI main effect. The effectiveness increases when DENTI changes from the low to the middle level and then decreases when DENTI changes from the middle level to the high level. This suggests saturation, since at the high level of PC/PCINT, eighty percent of all Red targets are potentially detectable.

(5) Although the three way interactions PC/PCINT x SENDLA x DENTI and PC/PCINT x SENS x DENTI were not statistically significant, study of these interactions reinforced the belief that the counterintuitive behavior of PC/PCINT was due to a saturation effect. Table F-8 shows the MOE 2 data for the interaction PC/PCINT x SENS x DENTI. When SENS is at its low level, the maximum is when both PC/PCINT and DENTI are at their middle levels. When SENS is at its middle and high levels, the behavior of PC/PCINT x DENTI is similar to the two-way interaction case.

3-7. WEAPON MOE. a. Main Effects

(1) The marginal means for the three weapon MOE (3, 5, and 7) are given in Table G-1. The two-way means for the three MOE are in Tables G-2, G-3, and G-4, and the ANOVA tables are in Tables G-5, G-6, and G-7. The significance of main effects is similar to that seen for MOE 2, 4, and 6 in paragraph 3-5a. Factors SENS (E) and DENTI (G) are highly significant, and WAIT (A) and DELTHR (C) are the least statistically significant for MOE 3 and 5. However, DELTHR (C) is highly significant for MOE 7.

(2) The main effects are illustrated in Figures G-1, G-2, and G-3. Again, for comparative purposes MOE 3 and MOE 5 are plotted on the same scale (Figure G-4), and MOE 5 and 7 are plotted on the same scale (Figure G-5). A comparison of Figure G-4 and Figure F-4 shows the similarity of the relationships between MOE 3 and MOE 5 and the relationships between MOE 2 and MOE 4. Likewise, Figures G-5 and F-5 show the similarity of the relationships of the total Red and Blue weapons killed to the relationships of the total Red and Blue personnel killed. Again, the two means were differenced to check the consistency of the relationships. Table 3-4, shows the differences (MOE 5 minus MOE 3) between corresponding marginal means. As before, the differences are relatively constant except those for DELTHR (C). The average difference is approximately 3,609.

Table 3-4. MOE 5 Marginal Means Minus MOE 3 Marginal Means

Factor	Level		
	0	1	2
A - WAIT	3,599	3,608	3,604
B - PC/PCINT	3,650	3,607	3,608
C - DELTHR	3,626	3,581	3,660
D - SENDLA	3,609	3,600	3,601
E - SENS	3,610	3,599	3,600
F - TYPE	3,595	3,606	3,607
G - DENTI	3,598	3,607	3,605

b. <u>Interaction Effects</u>

(1) Returning to the ANOVA tables in Tables G-5, G-6, and G-7 to examine interactions, we see a pattern of significant interactions similar to the pattern seen in the previous section. The interactions between PC/PCINT (B) and SENS (E) and between PC/PCINT (B) and DENTI (G) are highly singificant. Factors WAIT (A)

and DELTHR (C) again do not tend to interact with the other input factors. Table 3-5 shows the rank orderings of the statistical significances of the most highly significant interactions. A comparison of Table 3-5 and Table 3-3 shows the similarity of the patterns of significant interactions.

Table 3-5. Rank Order of Interactions Significances for MOE 3, 5, and 7

Interaction	MOE 3	MOE 5	MOE 7
BG - PC/PCINT x DENTI	1	1	3
BE - PC/PCINT x SENS	2	2	1
BD - PC/PCINT x SENDLA	4	4	4
EG - SENS x DENTI	5	5	5
DG - SENDLA x DENTI	-	-	2
EF - SENS x TYPE	3	3	-
DF - SENDLA x TYPE	6	-	6

(2) The same five interactions that were shown in the previous section, BG, BE, BD, EG, and DG, are graphically illustrated for MOE 3 in Figures G-6 through G-10. Figures G-11 through G-15 illustrate the interactions for MOE 5, and Figures G-16 through G-20 show the interactions for MOE 7.

(3) The two sets of three-way means, PC/PCINT x SENDLA x DENTI (BDG) and PC/PCINT x SENS x DENTI (BEG), that were extracted are shown in Tables G-8, G-9, and G-10. Although an examination of the tables shows that the minimum and maximum values do not shift like they did for MOE 2, 4, and 6, the plots of the means (Figures G-21, G-22, and G-23) look very similar to Figures F-21, F-22, and F-23 of the previous section.

c. Discussion. In general, the observations previously made for the personnel MOE also hold for the weapons MOE. Two additional effects were observed. First, the factor WAIT, which does not have a significant effect on the personnel MOE, has a significant effect upon the weapons MOE. This and the behavior of SENDLA indicate that delay times are much more critical in engaging the

mor mobile weapons targets. Secondly, with the exception of DELTHR and TYPE, input factor effects upon MOE 7 are mirror images of the effects upon MOE 5.

3-8. SIDE EXCURSION. a. Because of the previously mentioned unexpected effect of PC/PCINT (B) upon the personnel and weapons MOE, additional model runs were made. The additional runs involved the factors PC/PCINT (B), SENS (E), and DENTI (G). Factor B was set at additional incremental values between the original lower and upper values. The DIVOPS model was exercised with PC/PCINT (B) set at 0.001, 0.1, 0.2, 0.3, 0.4, and 0.8. SENS (E) was set at two of its original values--20 and 40; DENTI (G) was set at the same values that were used in the sensitivity experiment. WAIT (A) was set at 0, DELTHR (C) was set at 15, SENDLA (D) was set at 0, and TYPE (F) was set at 0. Table H-1 contains the model output (the seven MOE) for SENS = 20, and Table H-2 contains the output data for SENS = 40. After observing the constancy of output over the PC/PCINT (B) values for SENS = 20, some of the PC/PCINT (B) values were eliminated when the SENS = 40 runs were made.

b. No statistical analyses were performed on the side excursion data. A visual examination of the tables answered the question concerning the apparent counterintuitive PC/PCINT effect. For fixed values of the other input values, detections and Red kills increase and Blue kills decrease as PC/PCINT increased. However, the maximum (or minimum) is quickly reached. Thereafter, increasing PC/PCINT produces no impact upon the seven output variables analyzed. Results verified that PC/PCINT behaves intuitively. They also indicate the complex interrelationships among the input factors of DIVOPS. Once a combination of the input values of two factors reaches a threshold, increasing the value of a third input factor has no significant effect except for a small increase in the number of detections.

3-9. ANALYSIS SUMMARY. a. General

(1) Throughout the above, repeated mention has been made of a pattern and/or consistency between and among the MOE analyzed. The pattern of the significance of the model input factors upon the seven output variables is shown in Table 3-6. The table contains the levels of significance of the F-ratios in the seven ANOVA tables previously cited.

(2) With the exceptions of PC/PCINT (B), the influences of the input factors (main effects) upon the output variables were consistent with expectations. Concerning interaction effects, no strong expectations existed. The sensitivity analysis, however, identified strong interactions between some of the input factors.

b. SENDLA. The sensitivity of DIVOPS to SENDLA is important. SENDLA represents the time a sensor requires to process and communicate target information. Plans are to modify the DIVOPS Model by making SENDLA a function of the battle intensity and the priority of the target being reported. The sensitivity experiment results indicate that the modification is needed. Although the trend in effectiveness across all MOE decreases as SENDLA increases, the rate of decrease is not consistent across all MOE. A comparison of Figures E-1, F-1 and G-1 (total number of Red targets detected, Red personnel killed due to detection, and Red weapons killed due to detection, respectively) shows that in Figure E-1 a large decrease occurs between the low and middle level. In Figure F-1, a large decrease occurs between the middle and high levels, while in Figure G-1 the decrease is linear between all levels of SENDLA. Although the range of values over which SENDLA has its maximum effect on the MOE varies with the MOE, SENDLA does produce a strong effect.

c. TYPE. The DIVOPS Model is sensitive to TYPE across all MOE, however, the trend is not consistent across all MOE. For MOE 1, the greatest number of detections occurred at the high level of TYPE (all stationary sensors). For MOE 6 and 7 (Blue losses), the fewest losses occurred at the middle level of TYPE (an equal number of mobile and stationary sensors). For the remaining MOE (Red losses), most losses occurred at the low level of TYPE (all mobile sensors). Since there was no constant trend, the exchange ratios (Red to Blue) for total personnel and weapons losses were calculated. Table 3-7 contains the exchange ratios for the three levels of TYPE for personnel and weapon losses (MOE 4/MOE 6 and MOE 3/MOE 7). A t-test was performed to test equality of the row ratios. The personnel ratios (1.13 vs 1.02) were statistically different at the 0.05-level of significance. However, the difference between 2.80 and 2.74 was not statistically significant at the 0.05-level of significance.

Table 3-6. ANOVA Tests Significance Levels

Source	Measure of Effectiveness						
	1	2	4	6	3	5	7
A		0.05			0.001	0.001	0.05
B	0.001	0.001	0.001	0.001	0.001	0.001	0.001
C	0.05	0.001	0.001	0.001	0.001	0.001	0.001
D	0.001	0.001	0.001	0.001	0.001	0.001	0.001
E		0.001	0.001	0.001	0.001	0.001	0.001
F	0.001	0.001	0.001	0.001	0.001	0.001	0.01
G	0.001	0.001	0.001	0.001	0.001	0.001	0.001
AB	0.01	0.01	0.01				
AC							
AD							
AE							
AF	0.05						
AG	0.05						
BC		0.05	0.05			0.05	
BD	0.001	0.001	0.001	0.001	0.001	0.001	0.001
BE		0.001	0.001	0.001	0.001	0.001	0.001
BF	0.01	0.001	0.001				
BG	0.05	0.001	0.001	0.001	0.001	0.001	0.001
CD	0.01	0.01	0.01		0.01		0.05
CE	0.05					0.05	
CF							
CG		0.05			0.05	0.05	
DE							
DF	0.001	0.001	0.001	0.001	0.01		0.001
DG	0.001	0.001	0.001	0.001			0.001
EF		0.001	0.001	0.05	0.001	0.001	
EG		0.001	0.001	0.001	0.001	0.001	0.001
FG	0.001	0.05	0.05	0.05	0.05	0.05	

Table 3-7. Red to Blue Exchange Ratios by TYPE

Ratio	TYPE		
	0	1	2
Personnel (MOE 4/MOE 6)	1.13	1.13	1.02
Weapons (MOE 3/MOE 7)	2.74	2.80	2.74

CHAPTER 4

OBSERVATIONS

The seven DIVOPS Model output variables investigated are sensitive to the seven input factors.

1. WAIT had the least effect upon the output variables.

2. DELTHR and WAIT do not in general interact with the other input factors.

3. The PC/PCINT, SENDLA, SENS, TYPE, and DENTI interact strongly, and their interrelationships appear complex.

4. Variability in the Total Number of Red Personnel Killed (MOE 4) and the Total Number of Red Weapons Killed (MOE 5) is attributable to the variability in the Number of Red Personnel Killed Due to Detection (MOE 2) and the Number of Red Weapons Killed Due to Detection (MOE 3), respectively.

5. MOE 3 and MOE 5 are more sensitive to changes in SENDLA and WAIT than are MOE 2 and MOE 4.

6. None of the Personnel MOE nor the Weapons MOE can be predicted from the Total Number of Red Targets Detected (MOE 1).

7. The model directly reflects the effects of saturation of both sensors and fire support systems.

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APPENDIX A

STUDY CONTRIBUTORS

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APPENDIX B

REFERENCES

1. US Army Concepts Analysis Agency, Draft Study Plan, "Target Acquisition Systems Force Mix Evaluation Analysis (TASFMEA) 1977-1987," Bethesda, MD, April 1977.

2. BDM Service Company "DIVOPS: A Division-Level Combined Arms Engagement Model (Version 3)", Leavenworth, KS, October 1975.

APPENDIX C

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APPENDIX D

MEASURES OF EFFECTIVENESS DATA

Appendix D contains the complete set of output data from the 243 model runs of the DIVOPS sensitivity experiment. The data are preserved here for future possible utilization. The first column contains the cell identifications (See Chapter 2, paragraphs 2-1 and 2-2). The next seven columns contain model output data of the following seven output variables (MOE):

MOE	Definition
1	Total Number of Red Targets Detected
2	Number of Red Personnel Killed Due to Detection
3	Number of Red Weapons Killed Due to Detection
4	Total Number of Red Personnel Killed
5	Total Number of Red Weapons Killed
6	Total Number of Blue Personnel Killed
7	Total Number of Blue Weapons Killed

Table D-1. Measures of Effectiveness Data
(page 1 of 6 pages)

CELL ID	MOE 1	MOE 2	MOE 3	MOE 4	MOE 5	MOE 6	MOE 7
000000	0	0	0	4639	3626	7528	1607
000012	1017	2437	240	7148	3972	7500	1598
000021	1911	3393	298	9050	3908	7236	1539
001201	2247	7914	501	12370	4055	6191	1257
001210	124	1244	67	5885	3692	7523	1607
001222	6601	5934	370	10441	3974	6012	1219
002102	938	5756	333	10279	3914	7155	1520
002111	1312	5203	283	9845	3900	7232	1534
002120	71	625	34	5265	3659	7523	1607
010200	108	2167	118	5964	3699	7113	1449
010212	12470	4034	315	7837	3939	5564	1072
010221	22775	3262	203	7050	3854	5307	1067
011101	966	6625	454	10441	3996	6260	1031
011110	63	1013	52	4780	3622	7127	1451
011122	3068	5823	412	9614	3949	5970	1198
012002	103	1353	37	5771	3678	7128	1289
012011	134	1718	84	5508	3656	7124	1452
012020	7	43	2	3802	3575	7129	1452
020100	54	1493	75	5978	3677	6719	1369
020112	4681	4487	416	9122	4008	5416	1041
020121	3498	3837	285	8425	3881	5441	1054
021001	111	2007	116	6701	3722	6567	1344
021010	6	3	1	4600	3607	6764	1378
021022	284	2575	132	7083	3722	6404	1279
022002	1547	7557	459	12174	4079	5465	1057
022011	2347	6197	423	10719	4021	5563	1064
022020	123	1874	103	6280	3710	6660	1357
100202	7066	6233	566	8781	4074	6091	1234
100211	54132	3047	200	7597	3834	5350	1236
100220	265	2021	117	6723	3742	7525	1606
101100	171	2203	120	6854	3746	7526	1606
101112	822	4302	247	9577	3884	7388	1521
101121	362	2556	104	7211	3739	7524	1605
102001	126	1775	71	6443	3791	7529	1610
102010	106	1127	57	5768	3668	7523	1607
102022	159	1340	54	6028	3703	7529	1609
110102	2326	5143	474	8966	4016	6737	1276
110111	75055	2376	151	6694	3907	5341	1191
110120	269	2773	177	6579	3754	7101	1445
111000	122	2500	140	6297	3836	7117	1449
111012	243	2573	131	6370	3716	7117	1452

Table D-1. Measures of Effectiveness Data
(page 2 of 6 pages)

CELL ID	MOE 1	MOE 2	MOE 3	MOE 4	MOE 5	MOE 6	MOE 7
0111021	320	2978	144	6771	3733	7110	1448
0112201	239	3541	168	7347	3754	7110	1449
0112210	235	3150	198	6961	3774	7106	1445
0112222	186	2197	89	5993	3677	7114	1451
0120002	137	1390	128	6043	3692	6563	1346
0120011	16883	3236	217	7808	3884	5517	1086
0120020	224	2653	183	7269	3780	6470	1320
0121200	169	3249	224	7866	3784	6450	1286
0121212	855	6048	333	10666	3913	5889	1181
0121221	389	3849	177	8418	3769	6206	1270
0122101	239	3807	178	8355	3768	6291	1278
0122110	235	3403	249	8026	3839	6441	1313
0122122	196	2547	105	7002	3716	6505	1332
0200101	3506	5013	429	9545	4008	6806	1439
0200110	510	3856	261	8505	3881	7521	1603
0200122	54331	2182	134	6755	3753	6201	1338
0201002	187	2419	102	7136	3751	7529	1609
0201011	248	2287	96	6926	3726	7528	1609
0201020	183	1936	105	6580	3730	7529	1606
0202200	83	1184	56	5826	3681	7529	1607
0202212	211	2155	83	6838	3731	7529	1609
0202221	91	815	26	5525	3675	7531	1609
0210001	204	1360	129	5182	3715	7118	1451
0210010	315	3434	242	7250	3913	7104	1445
0210022	43221	2283	141	6053	3755	5987	1235
0211202	234	3541	168	7347	3754	7110	1449
0211211	423	4328	219	8092	3786	7058	1434
0211220	111	1503	79	5293	3662	7126	1451
0212100	83	1726	88	5515	3670	7122	1451
0212112	212	2930	127	6728	3713	7113	1450
0212121	93	1263	46	5052	3619	7123	1453
0220201	3644	6157	523	10894	4102	5342	1014
0220210	498	4900	471	9452	3925	5960	1222
0220222	32452	2217	136	6754	3795	5795	1193
0221102	239	3907	178	8355	3768	6291	1288
0221111	432	4749	226	9323	3315	6017	1233
0221120	113	1775	105	6382	3706	6648	1355
0222000	80	1986	114	6592	3715	6644	1354
0222012	138	2295	92	6938	3700	6629	1356
0222021	98	1562	58	6206	3666	6678	1364
1000202	2494	7403	535	11896	4080	6072	1225

Table D-1. Measures of Effectiveness Data
(page 3 of 6 pages)

CELL ID	MOE 1	MOE 2	MOE 3	MOE 4	MOE 5	MOE 5	MOE 7
1000211	18793	4377	309	8982	3979	5722	1143
1000220	146	1161	71	5803	3697	7529	1607
1001100	53	743	33	5383	3659	7528	1609
1001112	2137	5849	345	10528	3961	6813	1441
1001121	3341	6012	355	10489	3920	6597	1389
1002001	106	1449	60	6122	3692	7529	1609
1002010	6	0	0	4639	3626	7523	1607
1002022	177	1310	67	6000	3717	7523	1609
1010102	369	6029	464	9842	4005	6234	1273
1010111	6172	4695	353	8759	4021	5626	1084
1010120	74	933	54	4696	3626	7124	1451
1011000	6	1	0	3759	3573	7128	1380
1011012	207	2094	122	5887	3707	7120	1452
1011021	307	2256	148	6064	3735	7110	1450
1012201	1435	7758	521	11536	4038	5995	1196
1012210	123	1764	101	5554	3683	7121	1450
1012222	3404	5957	421	9757	3960	5920	1182
1020002	107	1711	122	6364	3732	6549	1341
1020011	467	2597	200	7174	3789	6191	1270
1020020	7	105	4	4702	3610	6764	1378
1021200	104	2383	146	6994	3744	6604	1346
1021212	3625	5362	390	9383	4027	5419	1042
1021221	5701	4463	318	9067	3964	5415	1042
1022101	750	6523	389	11151	3968	5802	1205
1022110	59	1123	62	5728	3665	6763	1377
1022122	1645	5610	338	10236	3918	5954	1201
1100101	1145	6340	346	10990	3960	7034	1493
1100110	468	3592	236	8245	3859	7522	1532
1100122	64831	2182	134	6755	3753	6201	1338
1101002	160	2135	89	6792	3722	7530	1610
1101011	265	2149	99	6833	3749	7530	1610
1101020	135	1187	63	5830	3689	7527	1607
1102200	114	1553	78	6201	3703	7529	1607
1102212	380	3200	141	7851	3771	7525	1605
1102221	182	1535	57	6220	3706	7523	1610
1110001	136	2520	111	6341	3698	7121	1453
1110010	210	2541	170	6344	3749	7113	1449
1110022	38637	2604	161	6407	3822	5905	1203
1111202	342	4267	219	9072	3807	7047	1434
1111211	707	5357	295	9168	3964	6723	1366
1111220	157	1951	109	5748	3691	7118	1449

Table D-1. Measures of Effectiveness Data
(page 4 of 6 pages)

CELL ID	MOE 1	MOE 2	MOE 3	MOE 4	MOE 5	MOE 6	MOE 7
1112100	115	2259	123	6055	3704	7118	1449
1112112	384	4049	199	7856	3786	7096	1445
1112121	186	2197	89	5993	3677	7114	1451
1120201	1222	7449	440	12077	4028	5686	1135
1120210	458	4621	192	9166	3891	6007	1232
1120222	32416	2217	136	6754	3795	5795	1193
1121102	341	4622	225	9185	3315	6068	1244
1121111	725	5591	295	10238	3348	5904	1215
1121120	158	2226	143	6836	3741	6570	1340
1122000	84	2105	123	6712	3723	6633	1352
1122012	144	2168	92	6799	3697	6648	1359
1122021	166	2221	89	6848	3699	6578	1346
1200000	169	2300	125	6947	3750	7527	1606
1200012	58523	2519	155	7103	3914	6140	1313
1200021	64831	2192	134	6755	3753	6201	1338
1201201	172	2183	88	6831	3807	7528	1608
1201210	211	2116	115	6761	3740	7527	1606
1201222	182	1535	57	6220	3706	7529	1610
1202102	100	1376	49	6086	3698	7531	1610
1202111	191	1943	61	6623	3721	7530	1609
1202120	68	617	29	5258	3655	7528	1607
1210200	185	3131	192	6937	3768	7108	1446
1210212	43223	2374	146	6145	3781	5973	1231
1210221	43221	2283	141	6053	3726	5387	1235
1211101	171	2396	128	6695	3714	7115	1449
1211110	214	2913	174	6727	3726	7103	1446
1211122	186	2197	89	5993	3677	7114	1451
1212002	94	1934	77	5709	3656	7129	1454
1212011	131	1926	77	5716	3649	7123	1452
1212020	70	987	49	4752	3620	7124	1451
1220100	131	3404	240	9028	3334	6406	1306
1220112	32306	2293	142	6838	3800	4971	1185
1220121	32416	2217	137	6754	3742	5795	1127
1221001	116	2482	106	7127	3716	6590	1349
1221010	161	2739	179	7355	3775	6559	1337
1221022	196	2547	105	7177	3717	6505	1332
1222202	100	2231	89	6879	3698	6525	1355
1222211	197	2989	127	7614	3736	6520	1335
1222220	72	1233	69	5842	3671	6696	1364
2000101	1301	6496	398	11146	4012	6769	1426
2000110	64	679	31	5317	3657	7528	1607

Table D-1. Measures of Effectiveness Data
(page 5 of 6 pages)

CELL ID	MOE 1	MOE 2	MOE 3	MOE 4	MOE 5	MOE 6	MOE 7
2000122	17582	4216	305	8812	3963	5831	1184
2001002	126	1674	74	6386	3724	7531	1611
2001011	224	1762	89	6448	3738	7529	1609
2001020	7	3	2	4642	3628	7528	1707
2002200	103	2761	70	6067	3696	7529	1607
2002212	2479	6351	371	10819	3934	6648	1398
2002221	3551	6359	350	10803	3907	6505	1369
2010001	127	2084	119	5908	3705	7120	1452
2010010	7	0	0	3759	3573	7128	1452
2010022	1244	3113	305	6916	3874	6653	1349
2011202	1621	7931	549	11545	4039	5893	1159
2011211	3795	6161	470	9848	4014	5755	1125
2011220	143	1556	100	5345	3683	7127	1385
2012100	53	1156	55	4922	3626	7119	1449
2012112	1174	5779	345	9549	3889	6399	1309
2012121	1706	5744	344	11026	3889	6292	1289
2020201	1759	7228	503	11756	4080	5360	1019
2020210	119	2007	125	6614	3724	6688	1362
2020222	16919	3143	200	7715	3870	5558	1101
2021102	837	6658	415	11293	3990	5301	1190
2021111	1812	5925	393	10399	3952	5722	1149
2021120	67	1020	61	5621	3664	6735	1444
2022000	5	5	2	4603	3608	6764	1378
2022012	121	1780	81	6429	3689	6672	1364
2022021	163	1828	89	6457	3698	6607	1352
2100000	134	1919	101	6563	3727	7526	1606
2100012	35147	3271	211	7832	3849	5926	1228
2100021	56544	2513	155	7095	3813	6140	1351
2101201	266	2372	129	7614	3757	7526	1608
2101210	284	2656	154	7306	3780	7525	1605
2101222	362	2556	107	7208	3738	7524	1605
2102102	171	2183	83	6831	3713	7528	1608
2102111	352	3016	130	7665	3760	7525	1605
2102120	108	987	48	5629	3674	7529	1607
2110200	185	3131	192	6937	3768	7108	1446
2110212	43223	2374	146	6145	3781	5973	1231
2110221	43221	2283	141	6053	3765	5387	1235
2111101	266	3763	182	7430	3769	7105	1449
2111110	287	3445	227	7263	3801	7101	1444
2111122	370	3424	161	7233	3751	7090	1452
2112002	94	1927	78	5700	3656	7130	1454

Table D-1. Measures of Effectiveness Data
(page 6 of 6 pages)

CELL ID	MOE 1	MOE 2	MOE 3	MOE 4	MOE 5	MOE 6	MOE 7
2112011	140	1843	81	5637	3653	7123	1452
2112020	96	1291	69	5081	3653	7128	1452
2120100	181	3404	240	8028	3817	6406	1306
2120112	32311	2296	142	6834	3799	5781	1186
2120121	32416	2217	137	6754	3795	5795	1191
2121001	116	2480	107	7126	3716	6589	1349
2121010	123	2059	130	6664	3729	6666	1358
2121022	329	3428	150	7887	3741	6323	1293
2122202	171	3126	140	7761	3751	6457	1322
2122211	365	4243	195	8807	3786	6159	1260
2122220	113	1775	169	6382	3706	6648	1245
2200202	301	3200	143	7844	3772	7527	1608
2200211	67832	2231	138	6804	3756	6203	1339
2200220	266	2031	117	6719	3741	7525	1606
2201100	89	1264	60	5907	3686	7529	1607
2201112	315	2739	114	7385	3743	7526	1607
2201121	183	1535	57	6220	3706	7529	1610
2202001	83	1194	42	5874	3676	7528	1609
2202010	109	1189	57	6080	3683	7529	1607
2202022	91	915	27	5525	3675	7531	1609
2210102	301	4012	200	7810	3788	7084	1444
2210111	43222	2343	144	6113	3777	5977	1233
2210120	269	2773	177	6579	3754	7101	1445
2211000	86	1827	94	5616	3676	7121	1450
2211012	217	2615	116	6410	3701	7118	1452
2211021	186	2197	49	5993	3677	7114	1451
2212201	96	1740	67	5532	3641	7124	1452
2212210	134	2077	112	5870	3692	7127	1451
2212222	93	1263	46	5052	3619	7129	1453
2220002	116	2479	107	7125	3716	6589	1349
2220011	27857	2510	155	7053	3817	5738	1173
2220020	262	2376	218	7599	3813	6391	1303
2221200	89	2115	124	6719	3723	6631	1352
2221212	328	3913	178	8470	3767	6275	1284
2221221	196	2547	105	7176	3717	6502	1332
2222101	86	2002	78	6650	3690	6648	1360
2222110	136	2401	150	7011	3747	6610	1347
2222122	93	1562	58	6206	3666	6674	1364

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APPENDIX E

DETECTION MOE

Appendix E contains summary statistics, statistical tests, and graphical illustrations of the Total Number of Red Targets Detected. Marginal and two-way means are presented and the analysis of variance (ANOVA) table is given. Main effects and some interaction effects are then shown graphically. Discussion of the analysis is given in Chapter 3, paragraph 3-5.

Table E-1. MOE 1 Marginal Means
(Total number of Red targets detected)

Factor	Level 0	Level 1	Level 2
A - WAIT	4,284	5,832	5,488
B - PC/PCINT	2,236	6,353	7,014
C - DELTHR	6,797	5,032	3,774
D - SENDLA	14,570	641	392
E - SENS	4,370	5,125	6,109
F - TYPE	551	6,949	5,103
G - DENTI	144	7,733	7,726

[illegible]

Table [illegible] Mean
(Total Number of Red Targets Detected)

Table E-3. MOE 1 ANOVA

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-ratio
A	2	107,071,266	53,535,633	1.29
B	2	1,085,992,279	542,996,140	13.08***
C	2	373,542,434	186,771,217	4.50*
D	2	10,667,683,290	5,333,841,645	128.52***
E	2	123,170,196	61,585,098	1.48
F	2	2,681,617,452	1,340,808,726	32.31***
G	2	3,107,126,189	1,553,563,094	37.43***
AB	4	644,940,197	161,235,049	3.88**
AC	4	30,916,129	7,729,032	<1.00
AD	4	215,041,606	53,760,402	1.30
AE	4	100,383,084	25,095,771	<1.00
AF	4	510,741,427	127,685,357	3.08*
AG	4	567,598,654	141,899,664	3.42*
BC	4	133,642,136	33,410,534	<1.00
BD	4	3,167,454,639	791,863,660	19.08***
BE	4	123,013,656	30,753,414	<1.00
BF	4	604,406,686	151,101,671	3.64**
BG	4	520,863,414	130,215,854	3.14*
CD	4	709,983,167	177,495,791	4.28**
CE	4	557,918,864	139,479,716	3.36*
CF	4	159,932,245	39,983,061	<1.00
CG	4	201,964,322	50,491,080	1.22
DE	4	83,140,991	20,785,248	<1.00
DF	4	4,981,311,243	1,220,327,811	29.40***
DG	4	5,260,221,560	1,315,055,390	31.69***
EF	4	165,652,116	41,413,029	<1.00
EG	4	190,328,013	47,582,003	1.15
FG	4	1,323,292,040	330,823,010	7.97***
R	144	5,976,299,787	41,502,082	
Total	242	44,275,249,082		

*-Significant at the 0.05-level of significance.

**-Significant at the 0.01-level of significance.

***-Significant at the 0.001-level of significance.

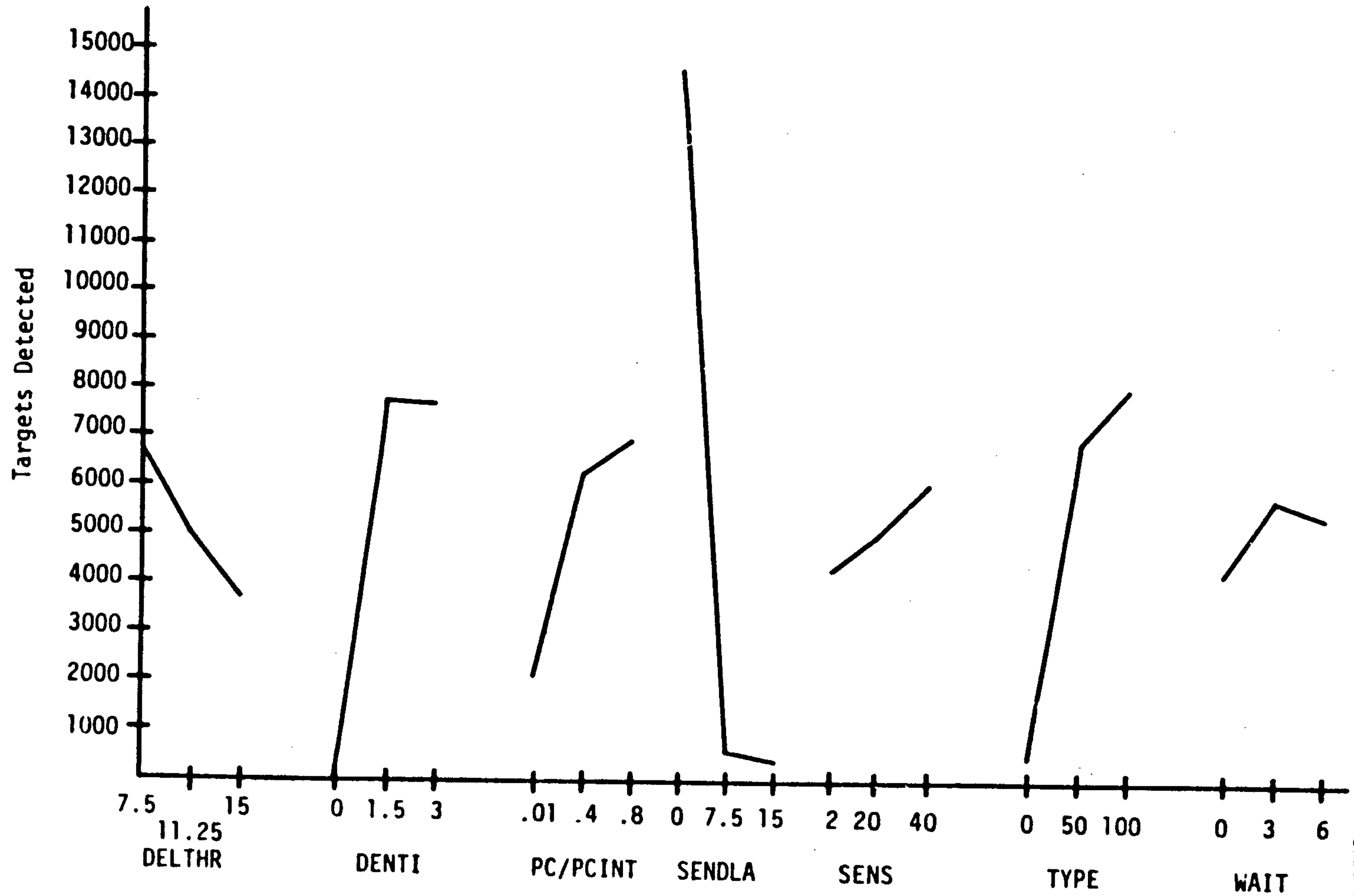

Figure E-1. MOE 1 Main Effects - Total Number of Red Targets Detected

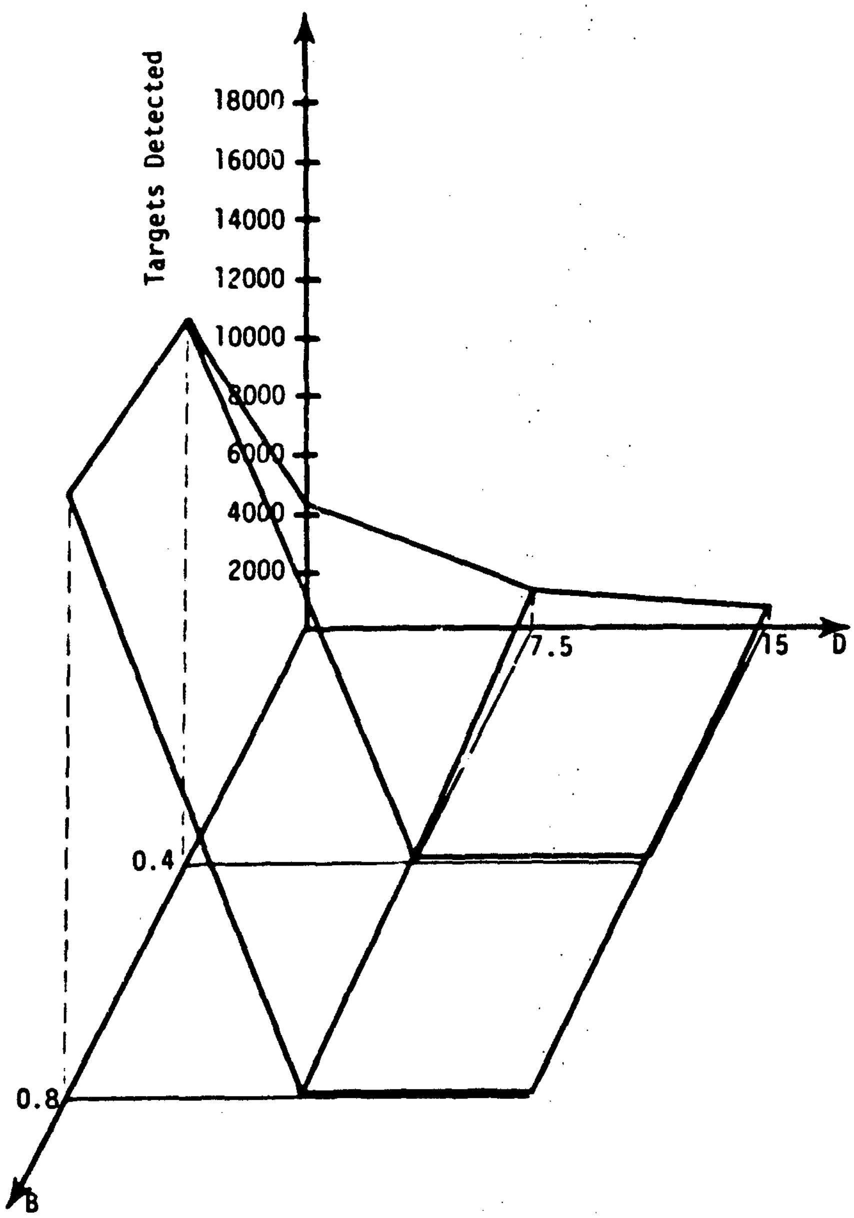

Figure E-2. MOE 1 PC/PCINT x SENDLA (BD) Interaction

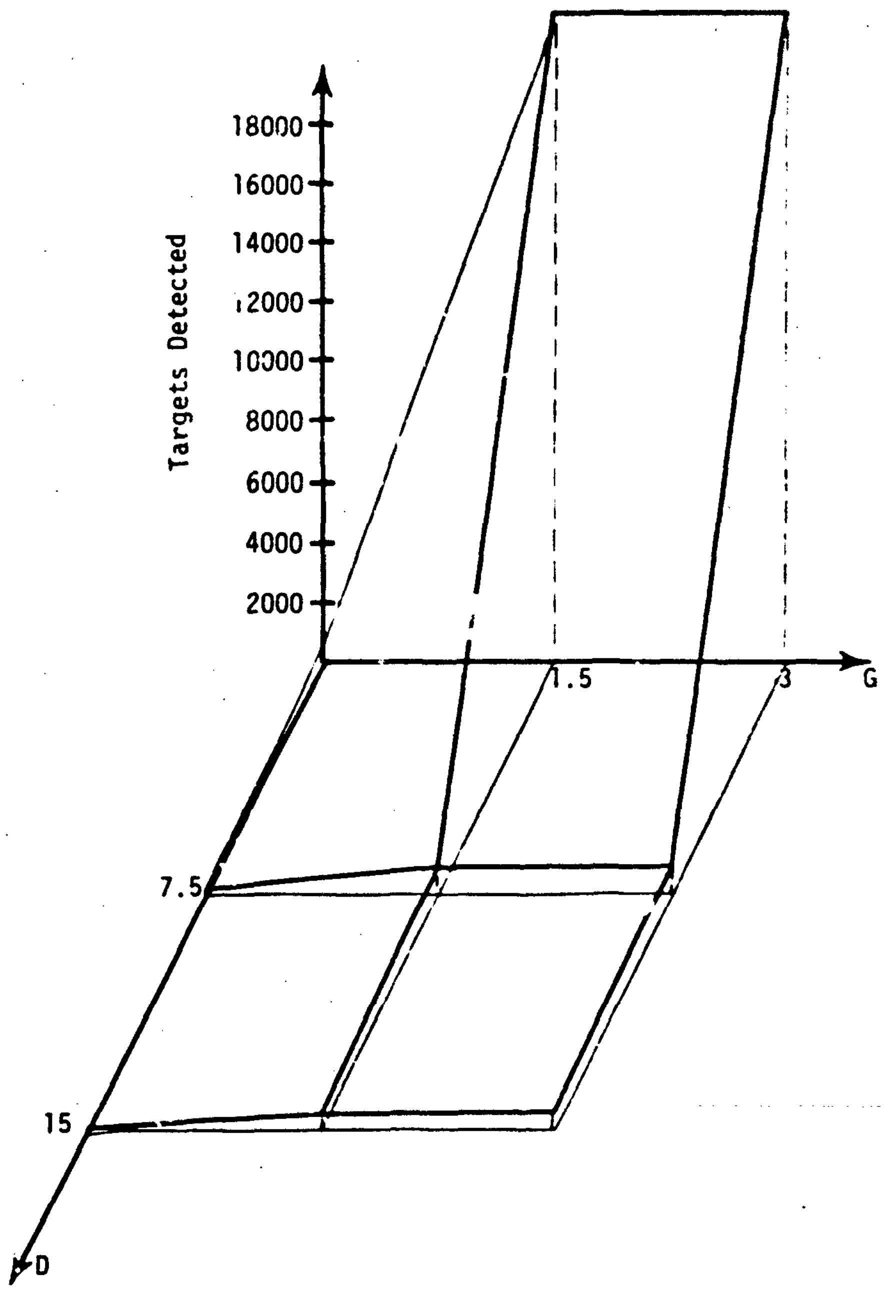

Figure E-3. MOE 1 SENDLA x DENTI (DG) Interaction

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APPENDIX F

PERSONNEL MOE

This appendix contains marginal and two-way means, ANOVA tables, and plots of main and interaction effects of the three Personnel MOE:

MOE 2 - Number of Red Personnel Killed Due to Detection

MOE 4 - Total Number of Red Personnel Killed

MOE 6 - Total Number of Blue Personnel Killed

Two additional plots (Figures F-4 and F-5) of main effects are given in order to facilitate the comparison between MOE 2 and MOE 4 and the comparison between MOE 4 and MOE 6. Following the two-factor interaction figures, the PC/PC NT x SENDLA x DENTI and PC/PCINT x SENS x DENTI three-way means are tabulated for each of the three MOE. Lastly, the PC/PCINT x SENS x DENTI interaction is graphically illustrated for each MOE. Analyses discusssion is given in Chapter 3, paragraph 3-6.

Table F-1. MOE 2, 4, and 6 Marginal Means

MOE 2, Red personnel killed due to detection

Factor	Level 0	Level 1	Level 2
A - WAIT	3,039	[illegible]	2,760
B - PC/PCINT	3,362	2,946	2,381
C - CELLR	[illegible]	2,896	3,111
D - SENGLA	3,073	3,097	2,519
E - SENS	1,913	3,233	3,493
F - TYPE	3,212	3,067	2,380
G - LENTI	1,876	3,418	3,365

MOE 4, total Red personnel killed

Factor	Level 0	Level 1	Level 2
A - WAIT	7,347	7,231	7,098
B - PC/PCINT	7,685	7,262	6,730
C - CELLR	7,274	6,706	7,696
D - SENGLA	7,378	7,428	6,870
E - SENS	6,267	7,639	7,770
F - TYPE	7,542	7,402	6,733
G - LENTI	6,207	7,801	7,668

MOE 6, total Blue personnel killed

Factor	Level 0	Level 1	Level 2
A - WAIT	6,734	6,732	6,784
B - PC/PCINT	6,600	6,793	6,857
C - CELLR	7,192	6,810	6,248
D - SENGLA	6,434	6,861	6,955
E - SENS	5,912	6,709	6,600
F - TYPE	6,944	6,677	6,729
G - LENTI	7,070	6,584	6,595

Table F-2. MOE 2 Two-Way Means
(Red personnel killed due to detection)

		B		
		0	1	2
	0	3,306	3,083	2,728
A	1	3,321	3,142	2,206
	2	3,458	2,614	2,207
			D	
	0	3,189	3,348	2,580
A	1	3,177	2,973	2,520
	2	2,851	2,970	2,459
			F	
	0	3,433	3,252	2,433
A	1	3,303	3,072	2,294
	2	2,989	2,876	2,415
			C	
	0	3,377	3,395	3,313
B	1	2,638	2,927	3,275
	2	2,032	2,365	2,744
			E	
	0	1,408	4,077	4,600
B	1	2,220	3,262	3,358
	2	2,110	2,511	2,520
			G	
	0	951	4,590	4,544
B	1	2,439	3,274	3,126
	2	2,239	2,479	2,424
			E	
	0	1,716	3,114	3,216
C	1	1,948	3,365	3,374
	2	2,073	3,371	3,889
			G	
	0	1,521	3,269	3,257
C	1	1,928	3,261	3,498
	2	2,180	3,814	3,339
			F	
	0	3,822	2,955	2,440
D	1	3,210	3,430	2,651
	2	2,692	2,816	2,050
			F	
	0	1,766	2,034	1,938
E	1	3,731	3,488	2,631
	2	4,228	3,679	2,572
			G	
	0	1,925	3,993	3,806
F	1	2,225	3,532	3,444
	2	1,479	2,819	2,844

		C	
	0	1	2
	2,951	2,847	3,319
A	2,554	2,958	3,157
	2,542	2,882	2,856
		E	
	1,977	3,425	3,716
A	1,880	3,350	3,439
	1,881	3,076	3,324
		G	
	1,989	3,536	3,591
A	1,841	3,577	3,251
	1,798	3,230	3,251
		D	
	3,081	3,519	3,485
B	3,221	3,227	2,391
	2,915	2,545	1,682
		F	
	3,911	3,139	3,036
B	3,260	3,292	2,288
	2,554	2,769	1,818
		D	
	3,221	2,684	2,142
C	2,840	3,248	2,599
	3,157	3,358	2,817
		F	
	3,024	2,813	2,209
C	3,218	2,982	2,486
	3,482	3,405	2,446
		E	
	2,229	3,402	3,587
D	2,036	3,566	3,689
	1,473	2,882	3,203
		G	
	2,375	3,585	3,257
D	1,765	3,707	3,820
	1,490	3,052	3,017
		G	
	1,367	2,169	2,201
E	1,994	3,980	3,877
	2,268	4,195	4,016

Table F-3. MOE 4 Two-way Means
(Total Red personnel killed)

			B				C	
		0	1	2		0	1	2
A	0	7,623	7,349	7,068	A	7,501	6,641	7,897
	1	7,648	7,493	6,553		7,190	6,762	7,742
	2	7,783	6,943	6,568		7,131	6,714	7,450
			D				E	
A	0	7,442	7,681	6,918	A	6,332	7,747	7,961
	1	7,513	7,302	6,879		6,232	7,702	7,760
	2	7,179	7,302	6,814		6,237	7,468	7,589
			F				G	
A	0	7,684	7,593	6,763	A	6,331	7,863	7,847
	1	7,656	7,408	6,630		6,185	7,934	7,575
	2	7,285	7,205	6,805		6,105	7,607	7,582
			C				D	
B	0	7,933	7,2[illegible]	7,880	B	7,423	7,815	7,816
	1	7,202	6,720	7,863		7,473	7,573	6,739
	2	6,688	6,156	7,345		7,237	6,897	6,056
			E				F	
B	0	5,761	8,460	8,825	B	8,185	7,456	7,413
	1	6,566	7,593	7,623		7,532	7,634	6,619
	2	6,473	6,853	6,863		6,908	7,116	6,166
			G				D	
B	0	5,235	8,972	8,848	C	7,754	7,325	6,745
	1	6,790	7,612	7,383		6,644	7,030	6,443
	2	6,596	6,820	6,773		7,736	7,930	7,422
			E				F	
C	0	6,377	7,745	7,701	C	7,532	7,456	6,836
	1	5,741	7,219	7,157		7,007	6,779	6,331
	2	6,683	7,954	8,452		8,087	7,971	7,031
			G				E	
C	0	6,124	7,890	7,809	D	6,571	7,739	7,826
	1	5,718	7,111	7,288		6,387	7,902	7,995
	2	6,76[illegible]	8,403	7,906		5,842	7,279	7,489
			F				G	
D	0	8,086	7,285	6,762	D	6,716	7,912	7,506
	1	7,550	7,752	6,983		6,112	8,038	8,135
	2	6,989	7,170	6,453		5,793	7,455	7,363
			F				G	
E	0	6,133	6,388	6,280	E	5,720	6,525	6,556
	1	8,064	7,840	7,014		6,338	8,370	8,210
	2	8,428	7,978	6,903		6,564	8,509	8,237
			G					
F	0	6,219	8,333	8,073				
	1	6,579	7,866	7,761				
	2	5,824	7,205	7,169				

Table F-4. MOE 6 Two-way Means
(Total Blue Personnel killed)

			B				C	
		0	1	2		0	1	2
A	0	6,597	6,769	6,836	A	7,192	6,813	6,198
A	1	6,580	6,821	6,796	A	7,178	6,797	6,221
A	2	6,622	6,790	6,940	A	7,206	6,819	6,326
			D				E	
A	0	6,424	6,814	6,964	A	6,985	6,687	6,530
A	1	6,382	6,364	6,951	A	6,923	6,672	6,602
A	2	6,497	6,904	6,950	A	6,917	6,768	6,667
			F				G	
A	0	6,760	6,706	6,737	A	7,057	6,581	6,564
A	1	6,845	6,660	6,691	A	7,067	6,580	6,550
A	2	6,927	6,665	6,759	A	7,087	6,592	6,673
			C				D	
B	0	7,043	6,596	6,160	B	6,473	6,599	6,727
B	1	7,232	6,887	6,261	B	6,382	6,955	7,043
B	2	7,303	6,946	6,323	B	6,447	7,028	7,097
			E				F	
B	0	7,050	6,498	6,250	B	6,648	6,600	6,551
B	1	6,875	6,790	6,715	B	6,891	6,690	6,799
B	2	6,900	6,838	6,834	B	6,994	6,741	6,837
			G				D	
B	0	7,124	6,338	6,337	C	6,788	7,356	7,433
B	1	7,038	6,676	6,666	C	6,526	6,926	6,977
B	2	7,049	6,739	6,783	C	5,989	6,301	6,455
			E				F	
C	0	7,305	7,202	7,069	C	7,284	7,166	7,127
C	1	7,017	6,771	6,641	C	6,930	6,736	6,763
C	2	6,503	6,153	6,088	C	6,319	6,129	6,297
			G				E	
C	0	7,527	7,036	7,014	D	6,657	6,388	6,257
C	1	7,117	6,669	6,642	D	7,066	6,804	6,712
C	2	6,567	6,048	6,130	D	7,102	6,935	6,829
			F				G	
D	0	6,694	6,244	6,365	D	7,020	6,130	6,152
D	1	6,885	6,827	6,870	D	7,091	6,753	6,738
D	2	6,954	6,960	6,952	D	7,100	6,870	6,896
			F				G	
E	0	7,087	6,896	6,842	E	7,092	6,884	6,849
E	1	6,789	6,652	6,686	E	7,076	6,536	6,514
E	2	6,656	6,483	6,659	E	7,043	6,332	6,424
			G					
F	0	7,077	6,720	6,736				
F	1	7,046	6,460	6,525				
F	2	7,089	6,573	6,525				

Table F-5. MOE 2 ANOVA

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-ratio
A	2	3,159,274	1,579,637	3.52*
B	2	39,301,978	19,650,989	43.81***
C	2	7,442,549	3,721,275	8.30***
D	2	17,277,724	8,638,862	19.26***
E	2	119,328,286	59,664,143	133.01***
F	2	33,566,807	16,783,403	37.42***
G	2	126,685,104	63,342,552	141.21***
AB	4	6,640,623	1,660,156	3.70**
AC	4	2,928,412	732,103	1.63
AD	4	1,585,056	396,264	<1.00
AE	4	1,021,760	255,440	<1.00
AF	4	1,870,703	467,676	1.04
AG	4	1,410,249	352,562	<1.00
BC	4	5,019,817	1,254,954	2.80*
BD	4	20,046,256	5,011,564	11.17***
BE	4	63,446,431	15,861,608	35.36***
BF	4	9,819,400	2,454,850	5.47***
BG	4	120,314,053	30,078,513	67.05***
CD	4	8,281,172	2,070,293	4.62**
CE	4	2,168,762	542,190	1.21
CF	4	1,637,780	409,445	<1.00
CG	4	4,745,232	1,186,308	2.64*
DE	4	1,478,873	369,718	<1.00
DF	4	10,613,035	2,653,259	5.91***
DG	4	9,523,737	2,380,934	5.31***
EF	4	23,883,855	5,970,964	13.31***
EG	4	14,071,905	3,517,976	7.84***
FG	4	5,704,823	1,426,206	3.18*
R	144	64,594,294	448,571	
Total	242	727,567,947		

*-Significant at the 0.05-level of significance.

**-Significant at the 0.01-level of significance.

***-Significant at the 0.001-level of significance.

Table F-6. MOE 4 ANOVA

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-ratio
A	2	2,507,304	1,253,652	2.79
B	2	37,100,428	18,550,214	41.35***
C	2	40,037,769	20,018,885	44.62***
D	2	15,428,242	7,714,121	17.19***
E	2	112,297,989	56,148,994	125.15***
F	2	30,294,939	15,147,470	33.76***
G	2	126,709,158	63,354,579	141.21***
AB	4	6,927,496	1,731,874	3.86**
AC	4	2,619,330	654,832	1.46
AD	4	1,900,902	475,226	1.06
AE	4	750,777	187,694	<1.00
AF	4	2,660,576	665,144	1.48
AG	4	1,092,485	273,121	<1.00
BC	4	4,940,113	1,235,028	2.75*
BD	4	18,509,733	4,627,433	10.31***
BE	4	61,495,131	15,373,783	34.27***
BF	4	10,206,214	2,551,553	5.69***
BG	4	127,061,444	31,765,361	70.80***
CD	4	6,753,182	1,688,295	3.76**
CE	4	3,004,106	751,027	1.67
CF	4	2,062,953	515,738	1.15
CG	4	4,279,574	1,069,893	2.38
DE	4	1,532,457	383,114	<1.00
DF	4	9,802,076	2,450,519	5.46***
DG	4	10,637,912	2,659,478	5.93***
EF	4	20,253,550	5,063,387	11.29***
EG	4	14,321,368	3,580,342	7.98***
FG	4	6,133,783	1,533,446	3.42*
R	144	64,605,101	448,647	
Total	242	745,926,090		

*, **, *** See Table F-5.

Table F-7. MOE 6 ANOVA

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-ratio
A	2	138,461	69,230	1.33
B	2	2,919,083	1,459,542	28.09***
C	2	36,527,566	18,263,783	351.50***
D	2	12,484,368	6,242,184	120.13***
E	2	4,947,703	2,473,852	47.61***
F	2	1,185,529	592,765	11.41***
G	2	12,474,534	6,237,267	120.04***
AB	4	221,764	55,441	1.07
AC	4	129,738	32,434	<1.00
AD	4	158,805	39,701	<1.00
AE	4	337,029	84,257	1.62
AF	4	338,635	84,659	1.63
AG	4	121,032	30,258	<1.00
BC	4	322,422	80,606	1.55
BD	4	2,210,643	552,661	10.64***
BE	4	4,540,105	1,135,026	21.84***
BF	4	365,789	91,447	1.76
BG	4	2,599,535	649,884	12.51***
CD	4	566,086	141,521	2.72*
CE	4	463,481	115,870	2.23
CF	4	351,695	87,924	1.69
CG	4	118,971	29,743	<1.00
DE	4	140,687	35,172	<1.00
DF	4	1,794,999	448,750	8.64***
DG	4	4,449,714	1,112,428	21.41***
EF	4	537,136	134,284	2.58*
EG	4	1,995,797	498,949	9.60***
FG	4	556,108	139,027	2.68*
R	144	7,482,223	51,960	
Total	242	100,479,640		

*
**
*** } See Table F-5.

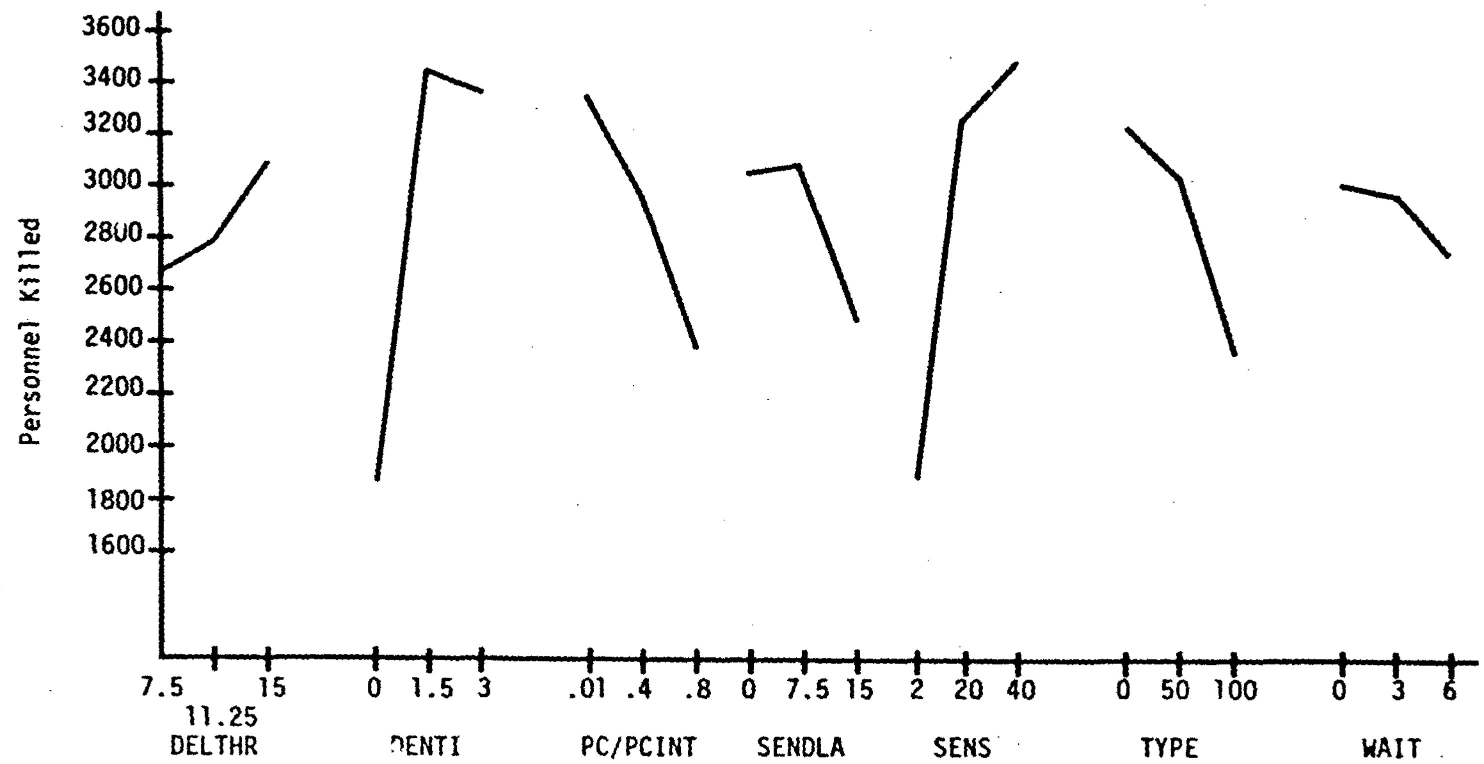

Figure F-1. MOE 2 Main Effects - Red Personnel Killed Due to Detection

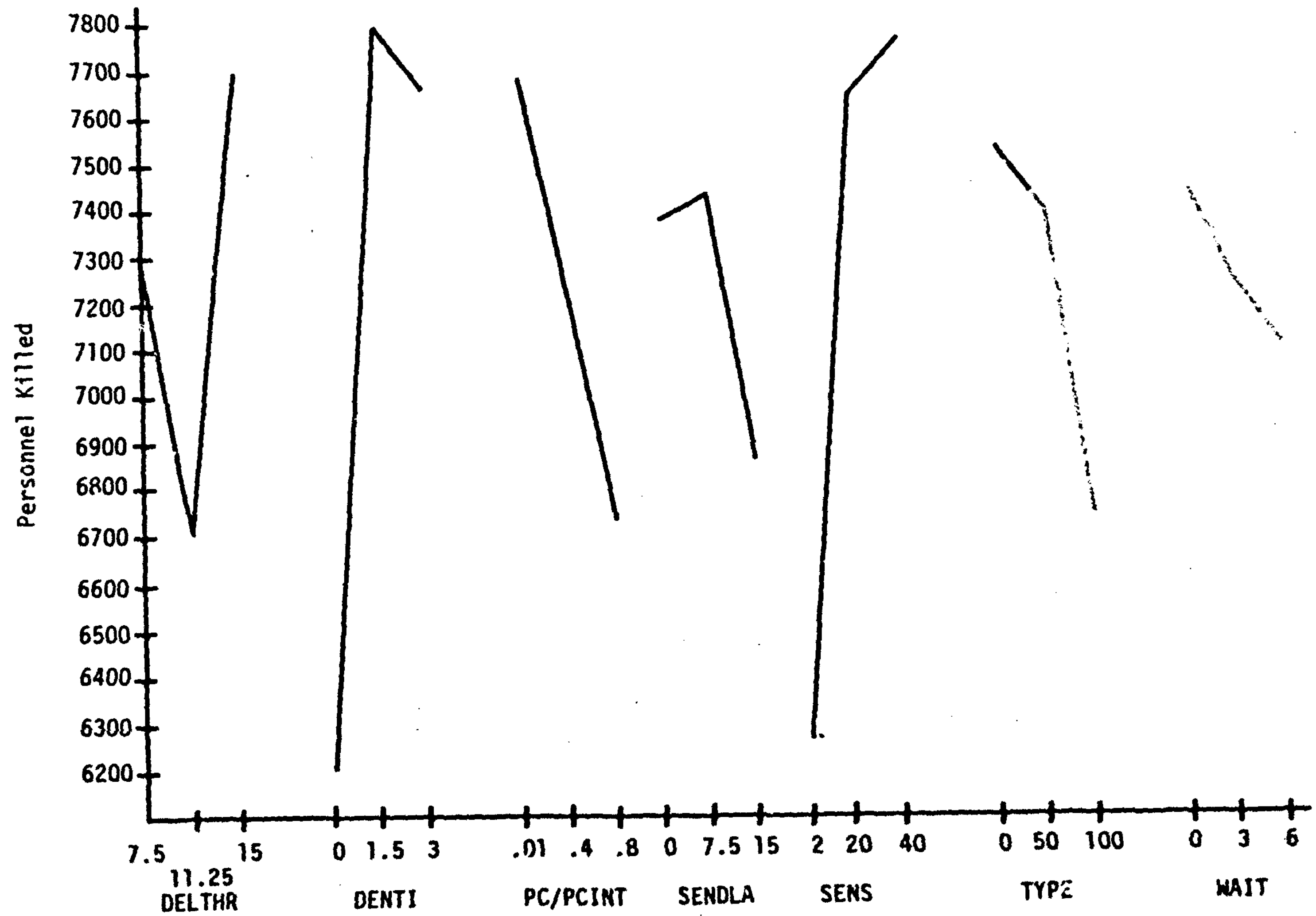

Figure F-2. MOE 4 Main Effects - Total Red Personnel Killed

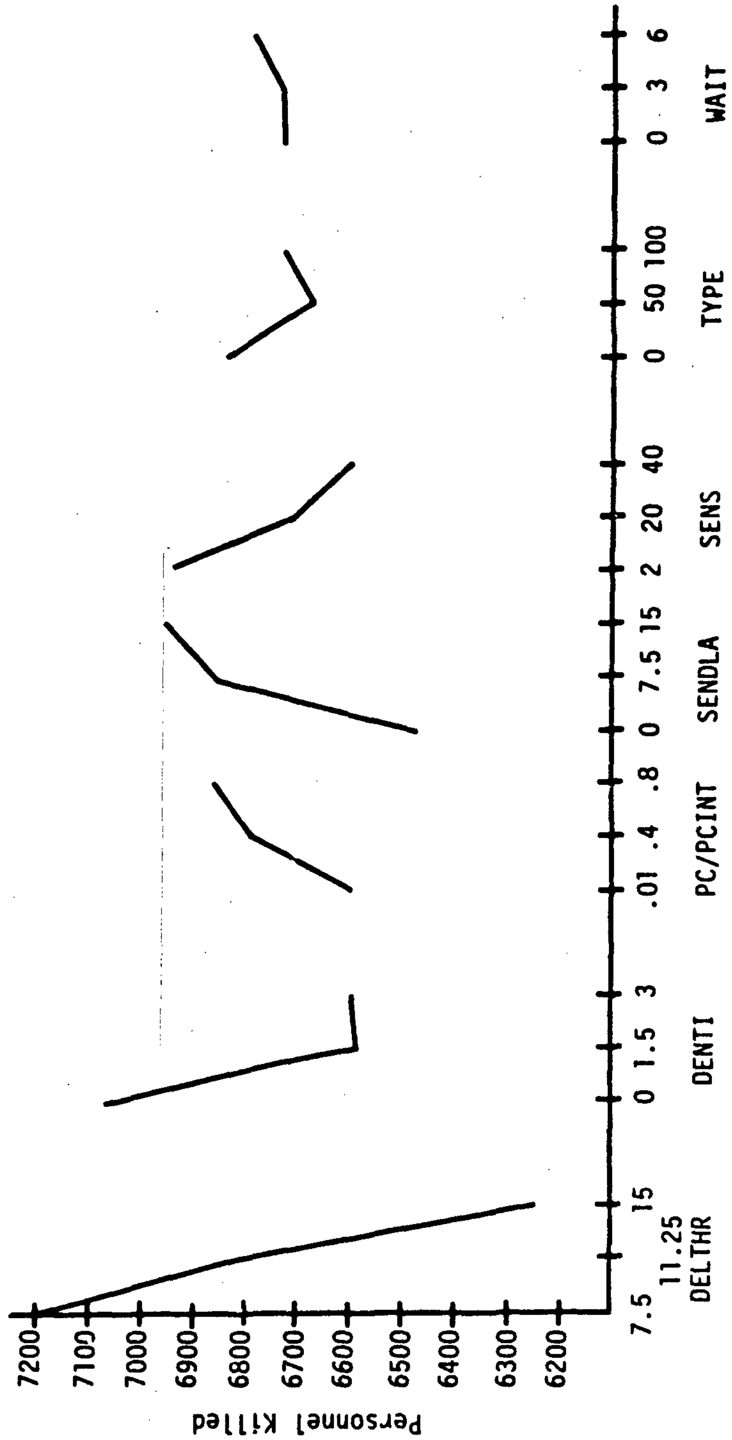

Figure F-3. MOE 6 Main Effects - Total Blue Personnel Killed

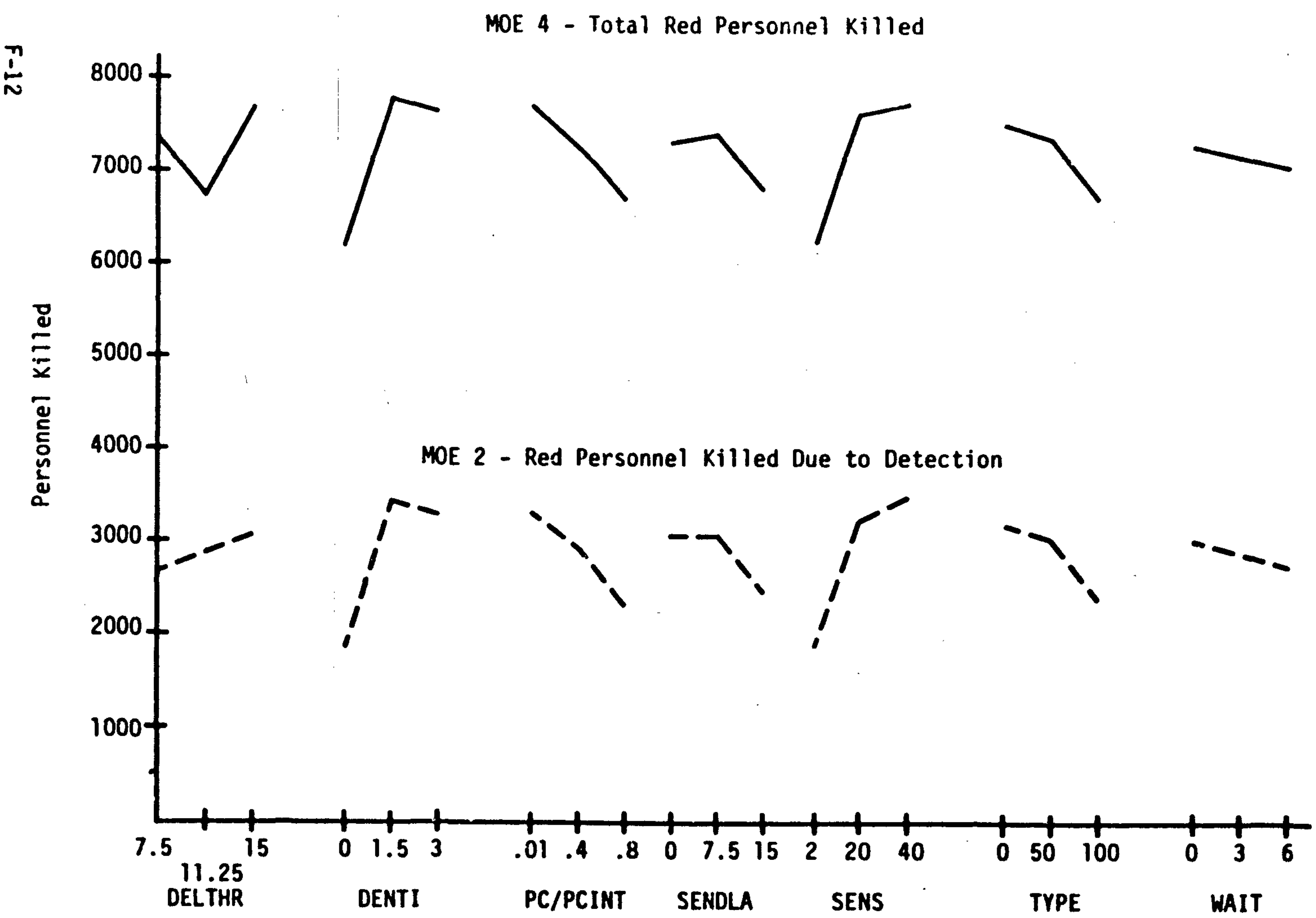

Figure F-4. MOE 2 and MOE 4 Main Effects

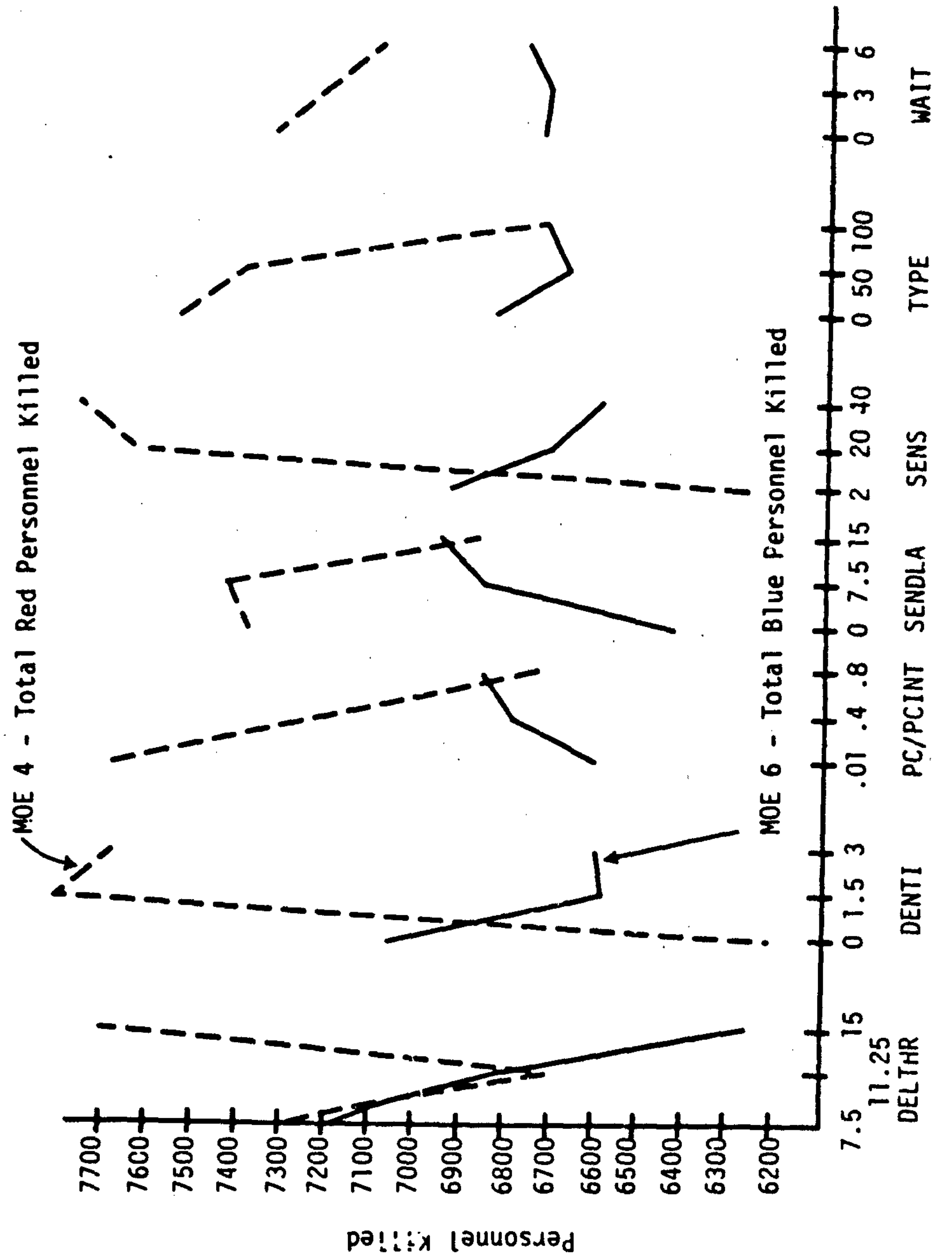

Figure F-5. MOE 4 and MOE 6 Main Effects

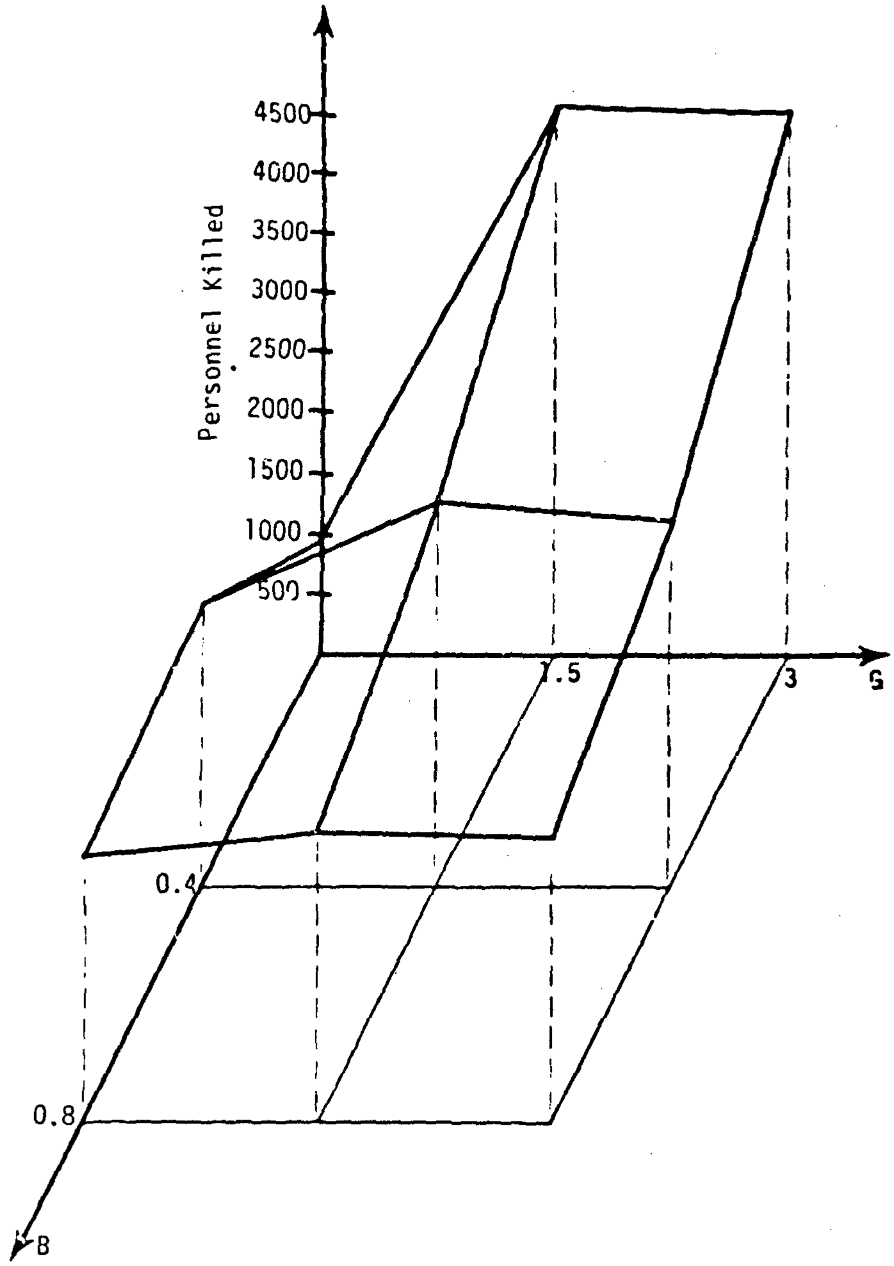

Figure F-6. MOE 2 PC/PCINT x DENTI (BG) Interaction

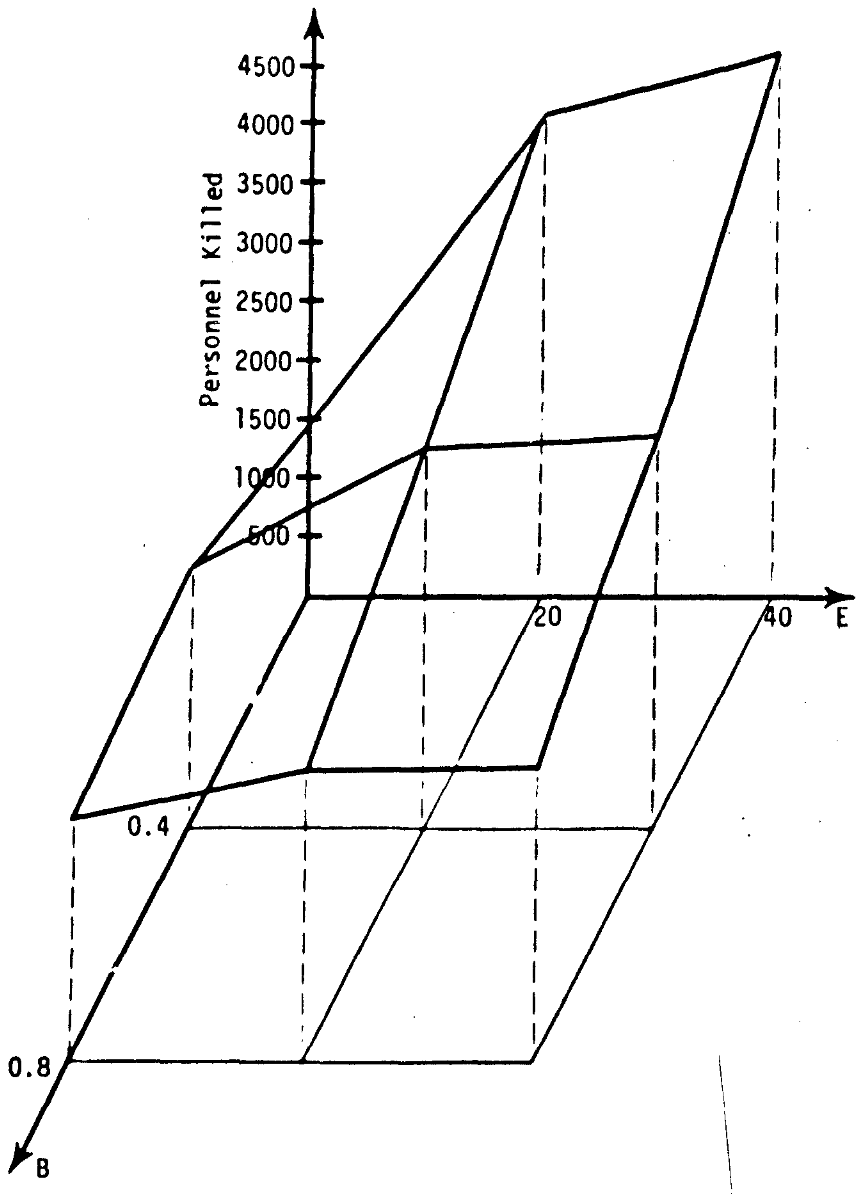

Figure F-7. MOE 2 PC/PCINT x SENS (BE) Interaction

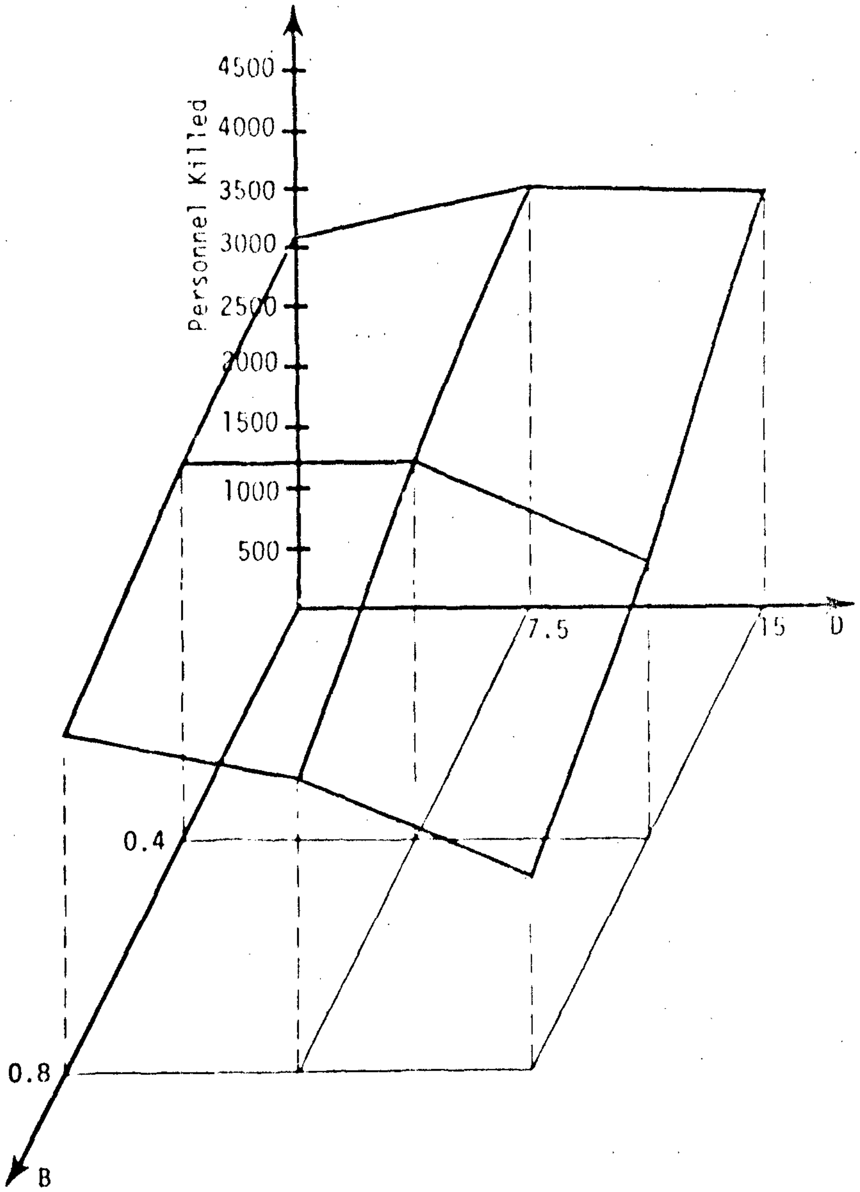

Figure F-8. MOE 2 PC/PCINT x SENDLA (BD) Interaction

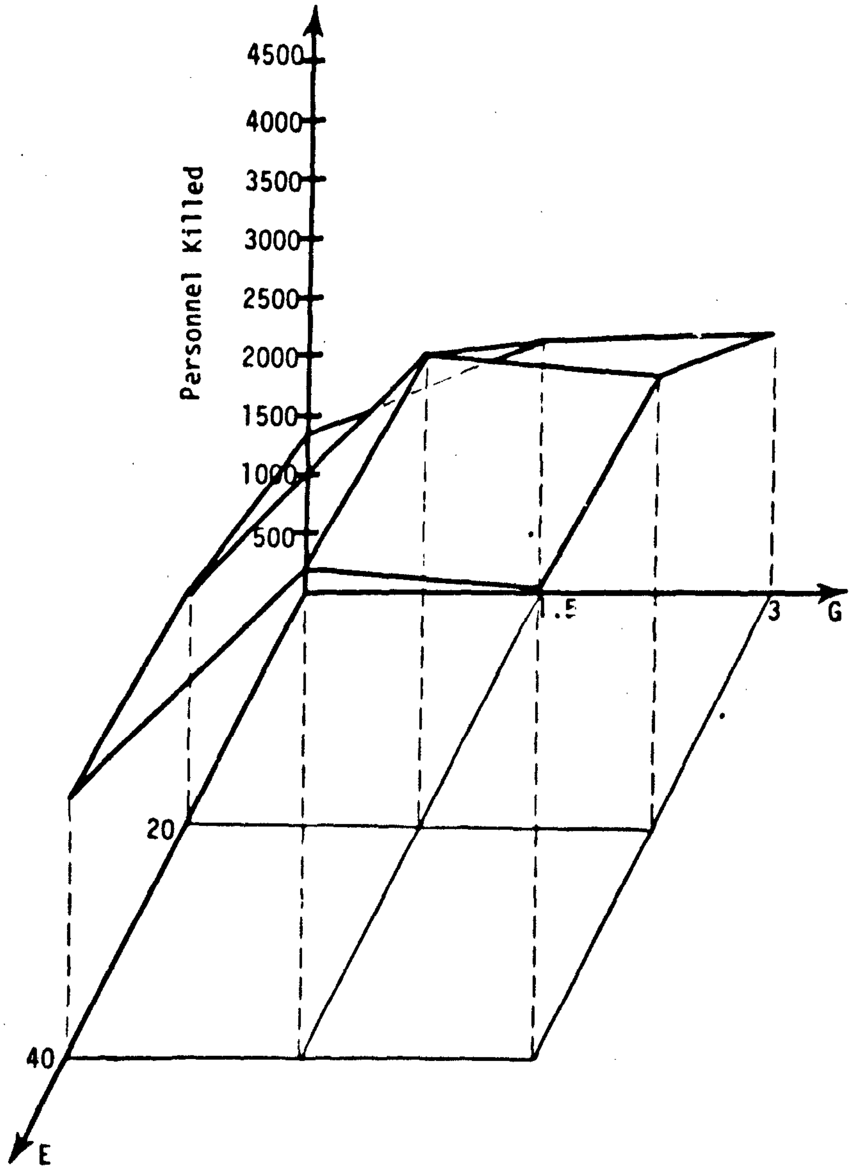

Figure F-9. MOE 2 SENS x DENTI (EG) Interaction

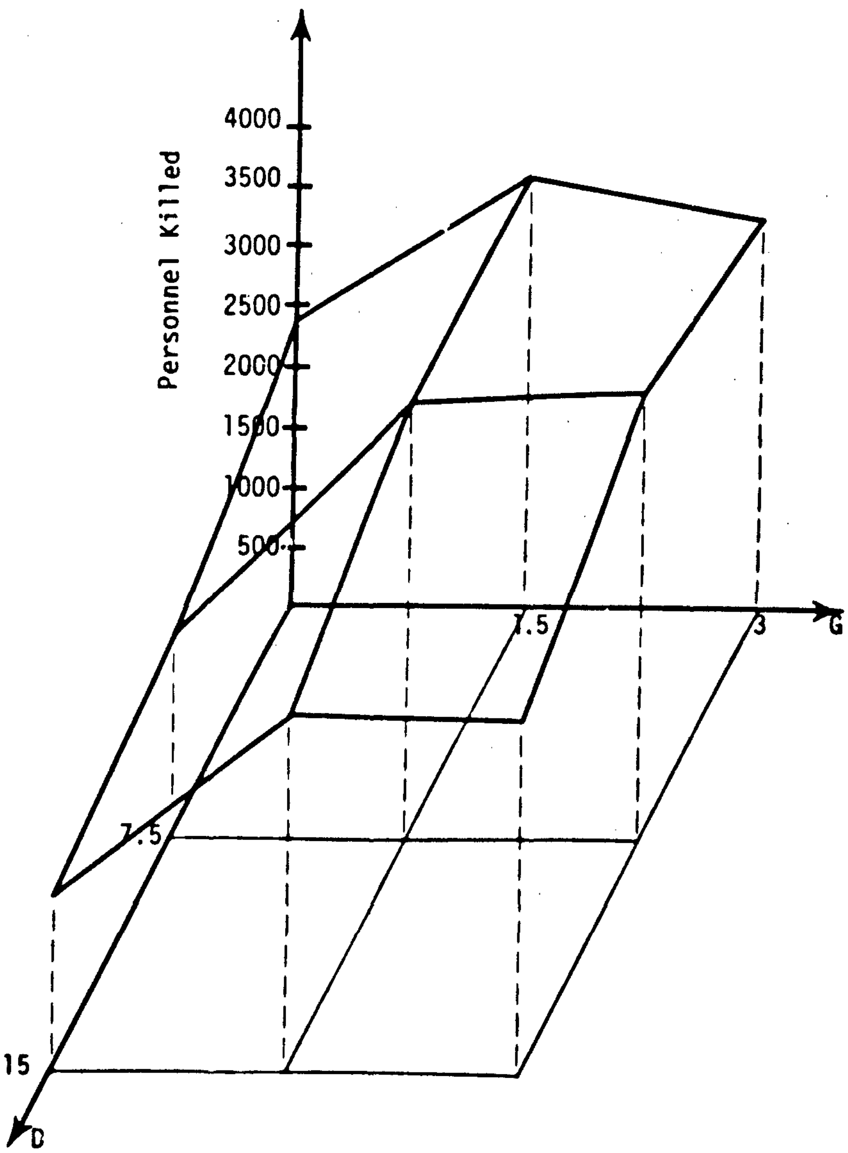

Figure F-10. MOE 2 - SENDLA x DENTI (DG) Interaction

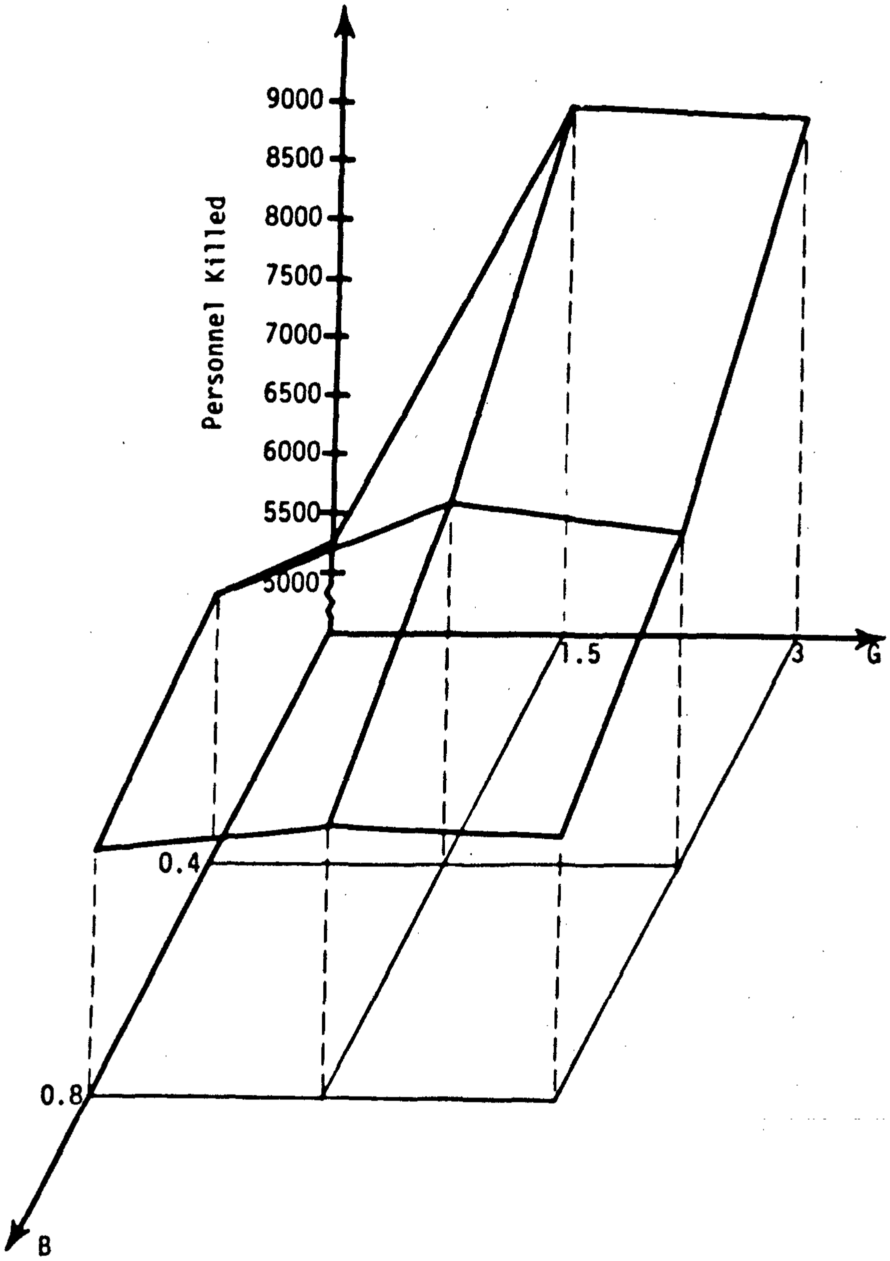

Figure F 11. MOE 4 PC/PCINT x DENTI (BG) Interaction

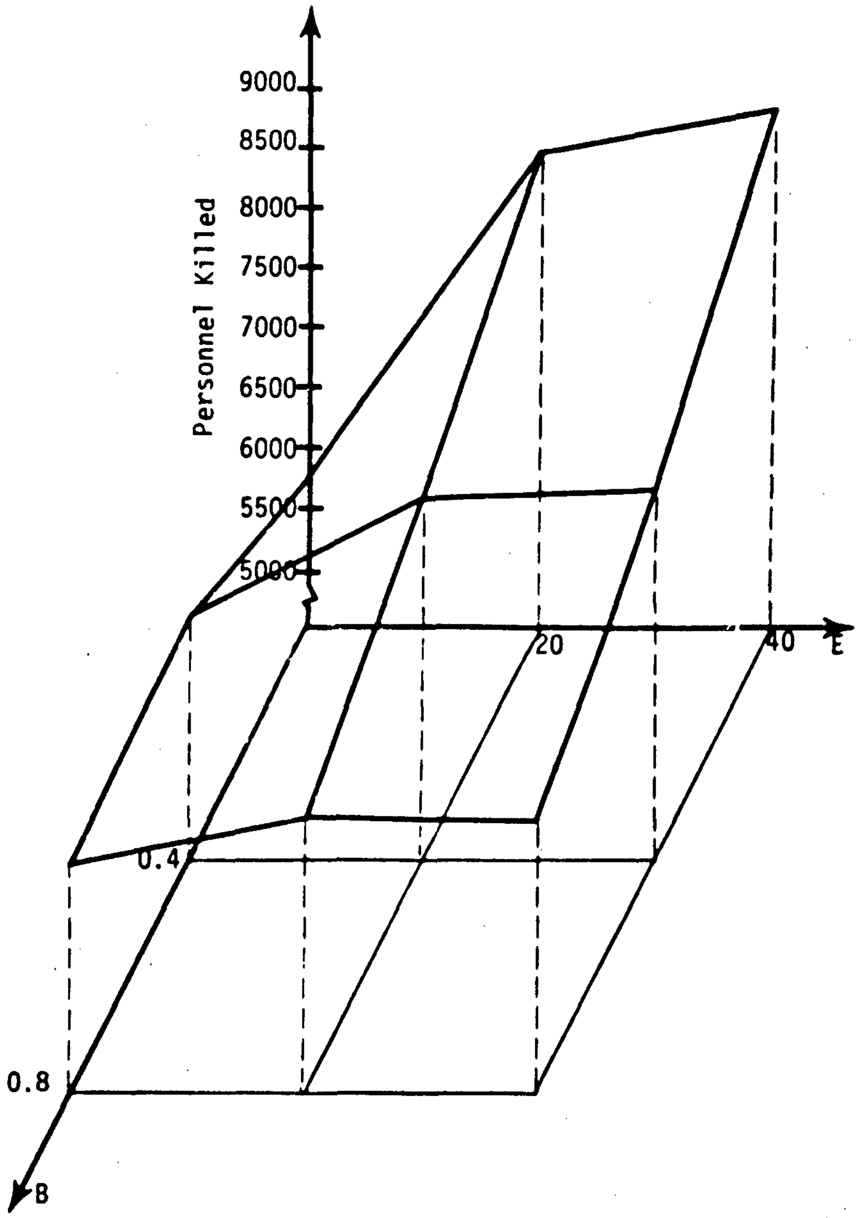

Figure F-12. MOE 4 PC/PCINT x SENS (BE) Interaction

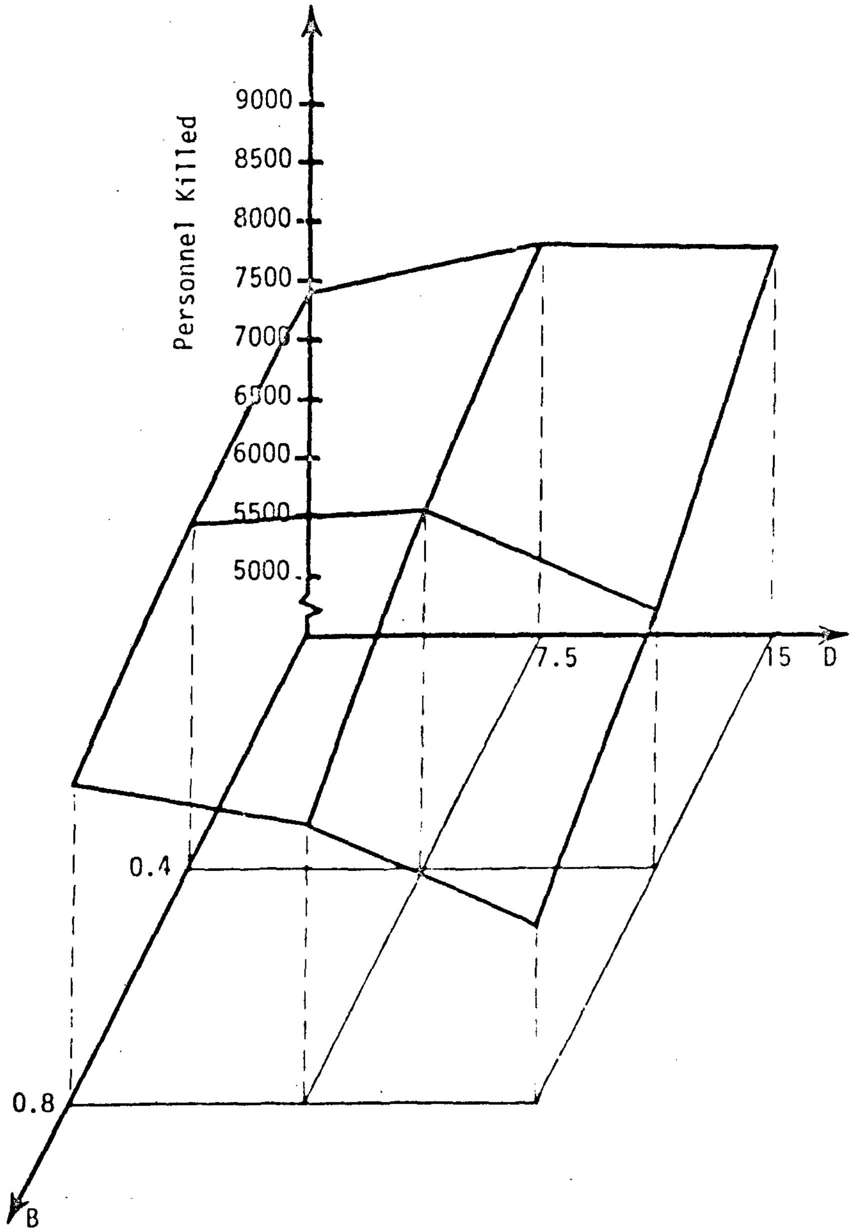

Figure F-13. MOE 4 PC/PCINT x SENDLA (BD) Interaction

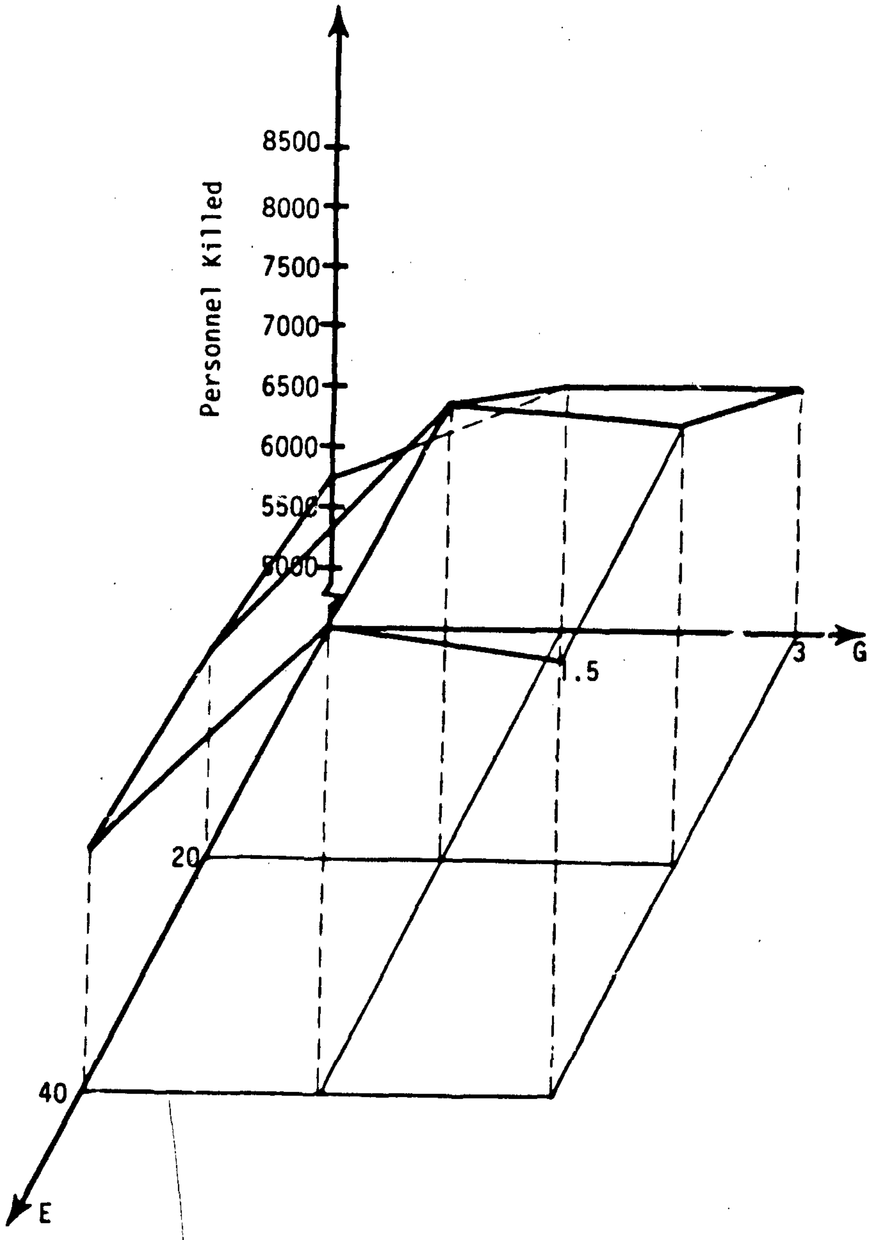

Figure F-14. MOE 4 SENS x DENTI (EG) Interaction

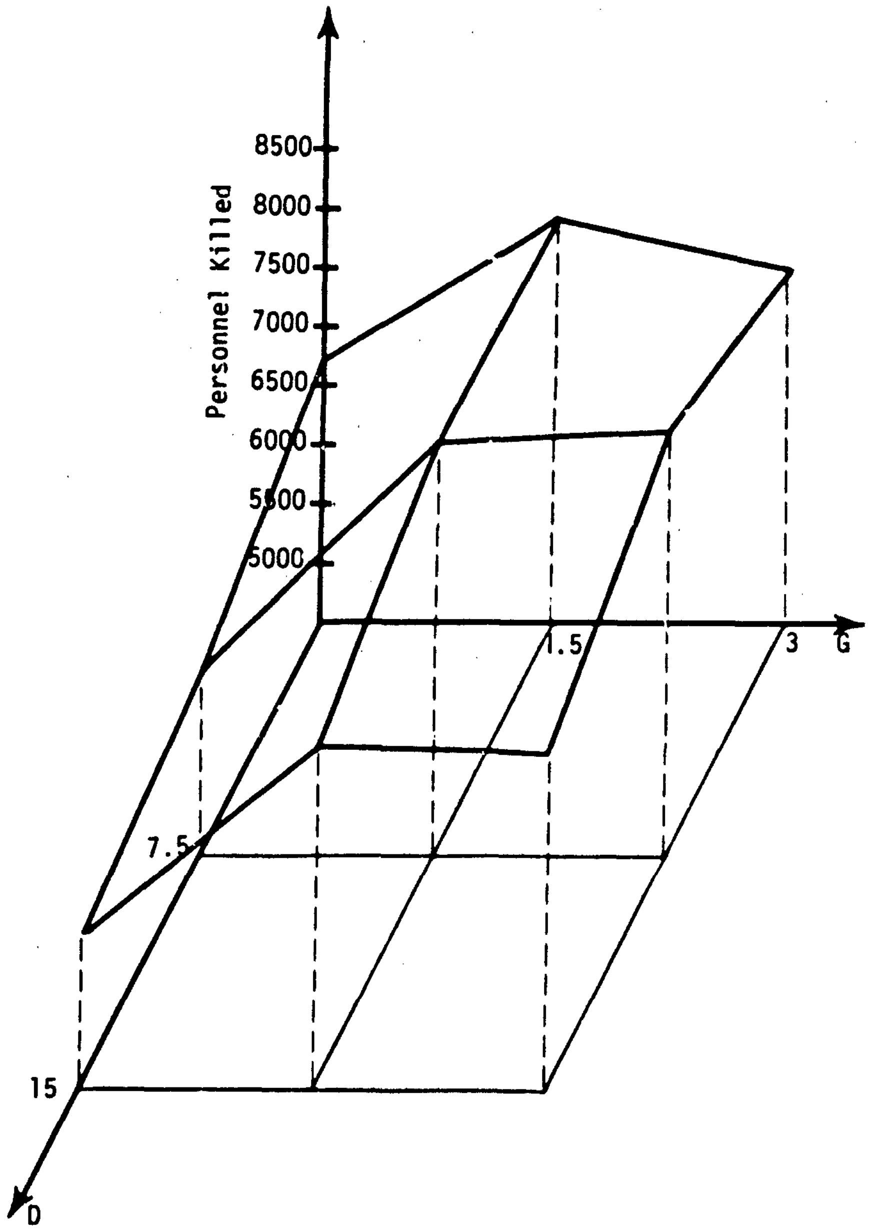

Figure F-15. MOE 4 SENDLA x DENTI (DG) Interaction

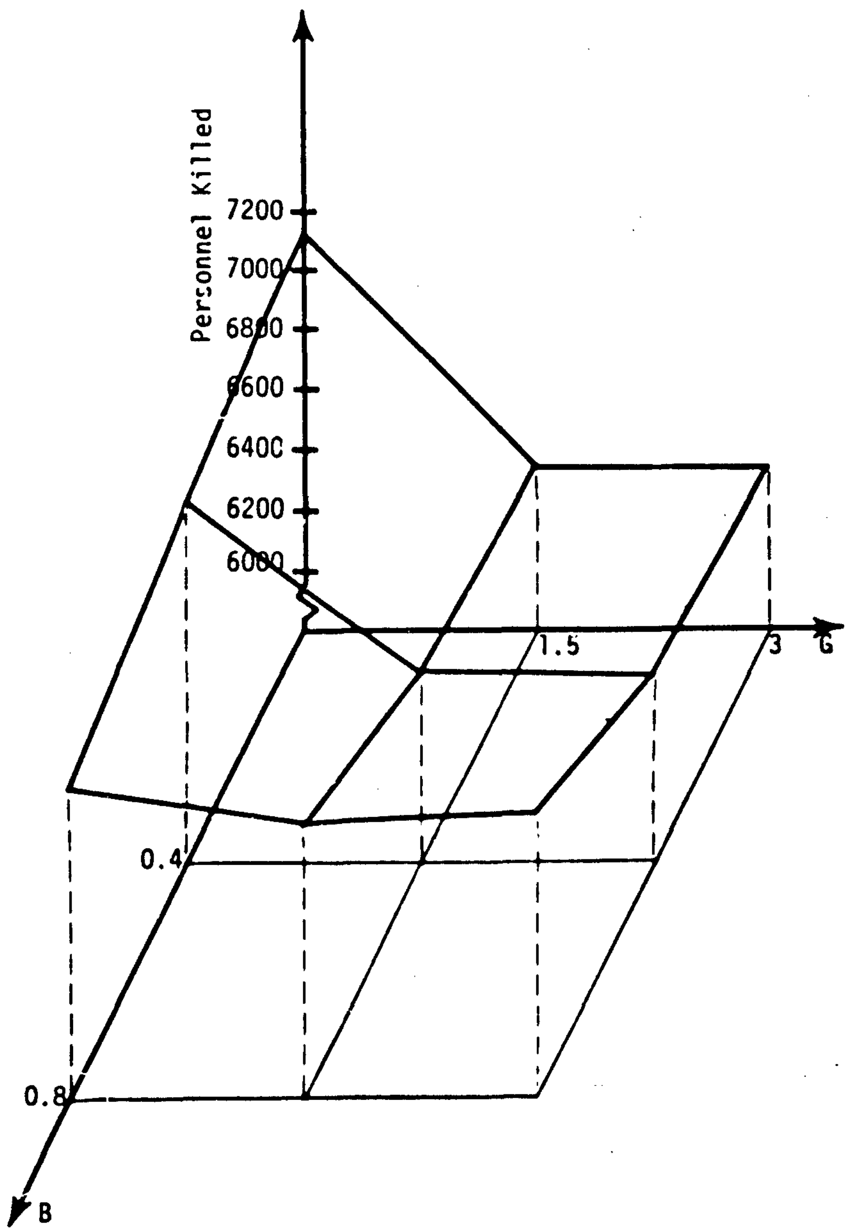

Figure F-16. MOE 6 PC/PCINT x DENTI (BG) Interaction

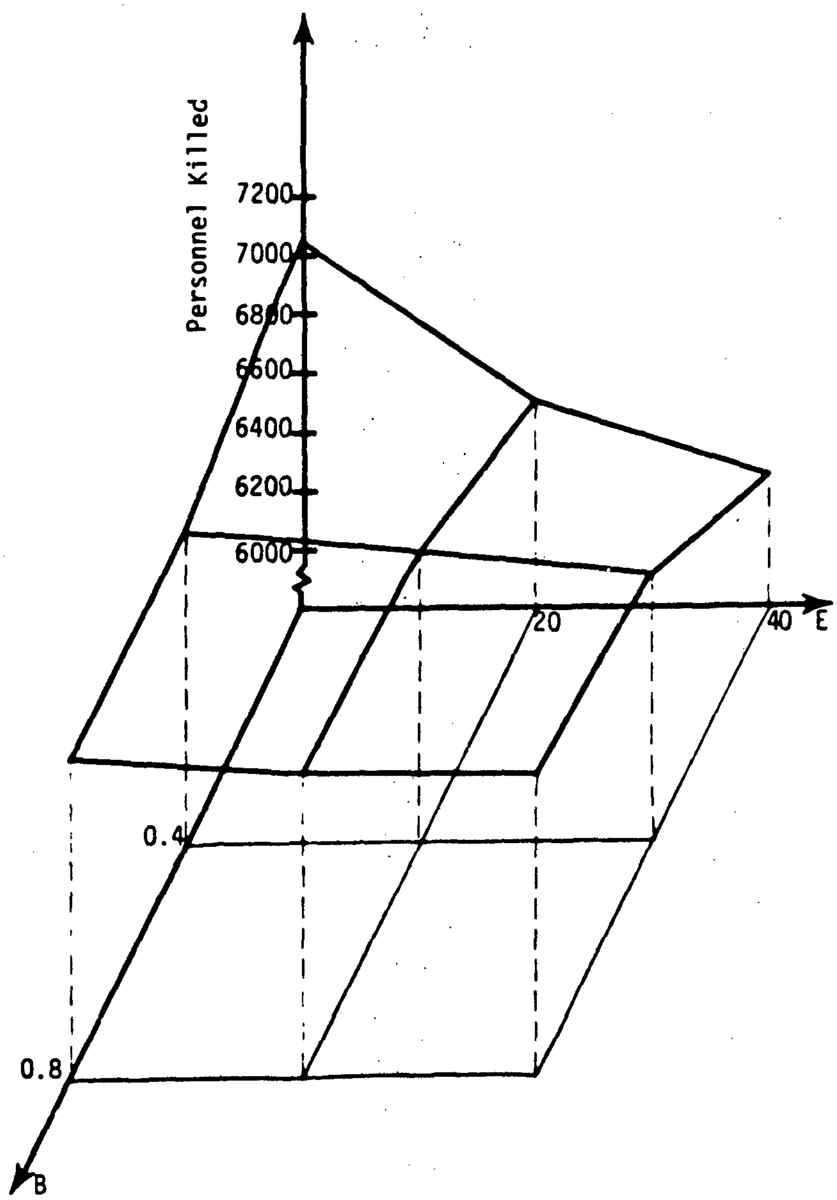

Figure F-17. MOE 6 PC/PCINT x SENS (BE) Interaction

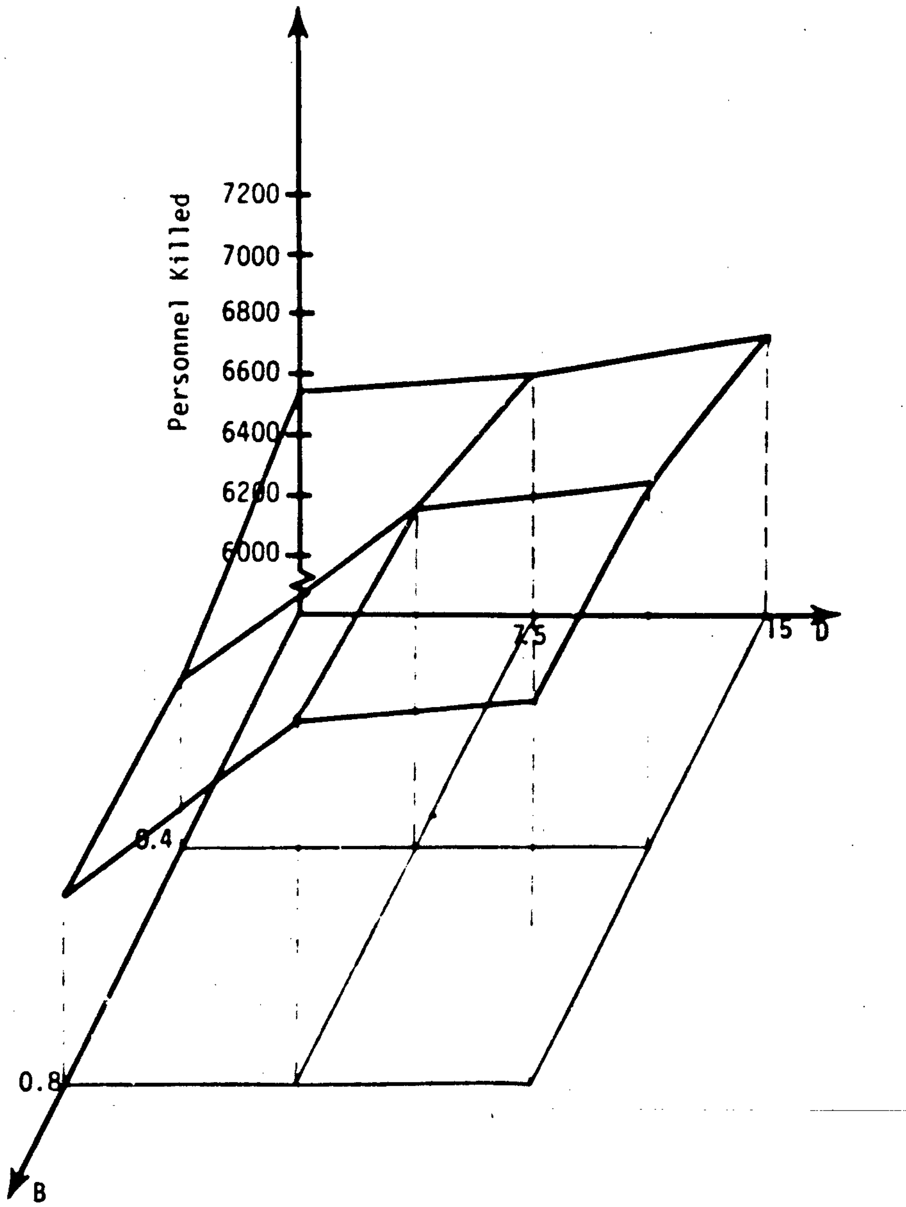

Figure F-18. MOE 6 PC/PCINT x SENDLA (BD) interaction

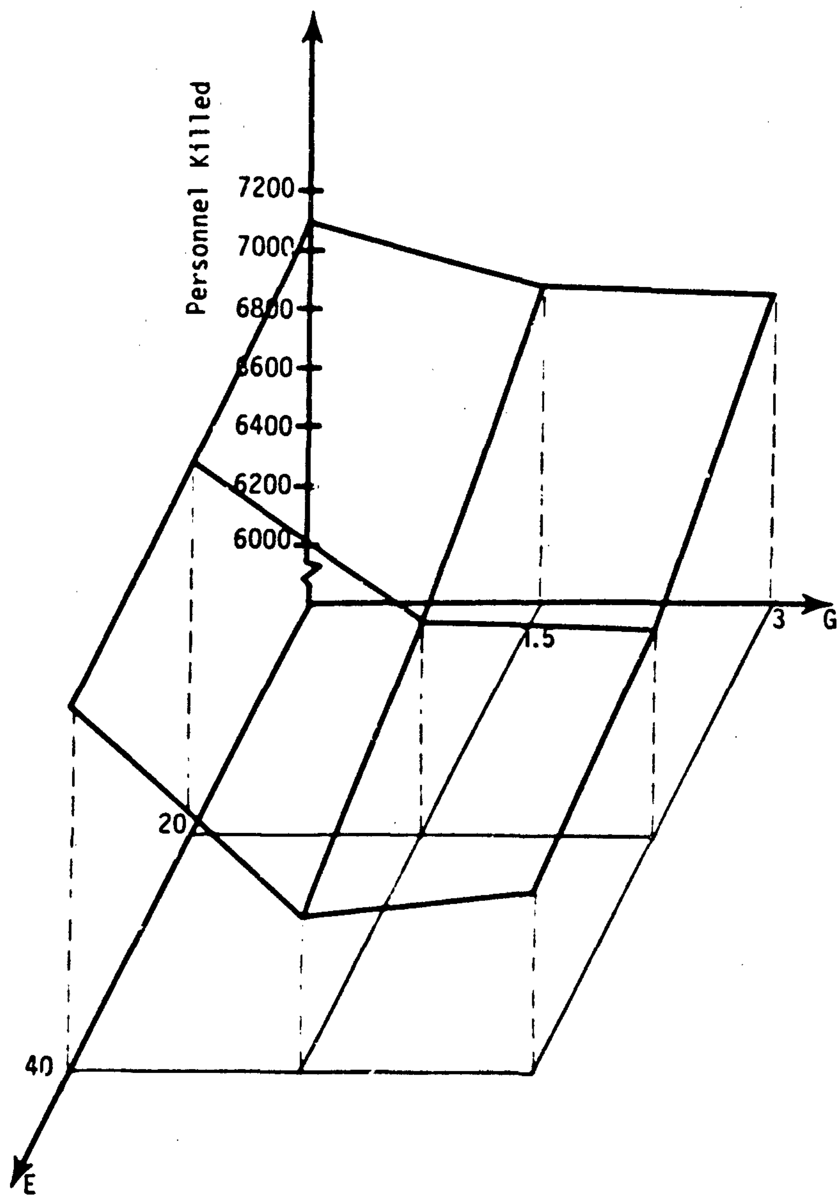

Figure F-19. MOE 6 SENS x DENTI (EG) Interaction

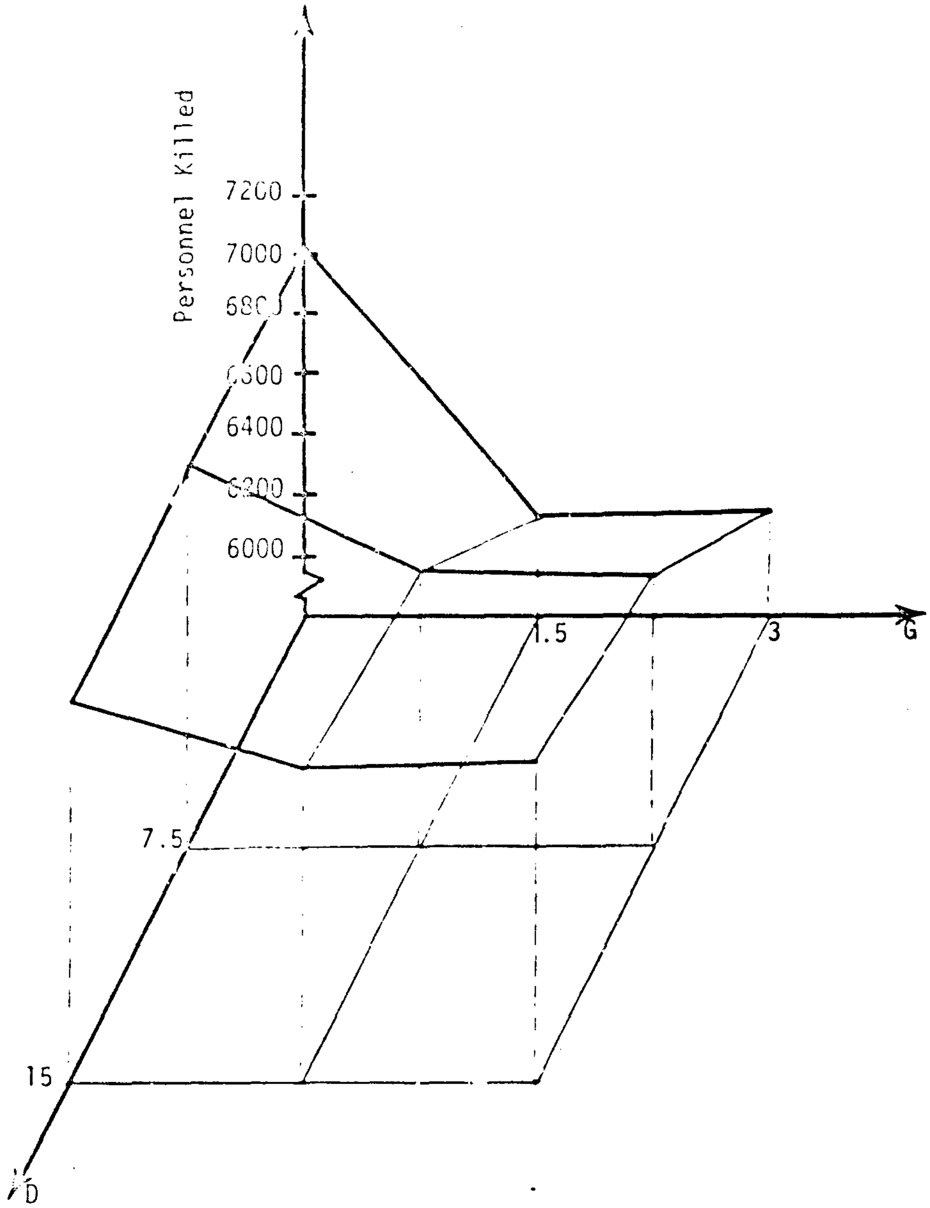

Figure F-20. MOE 6 SENDLA x DENTI (DG) Interaction

Table F-8. MOE 2 BDG and BEG Three-way Means

		D								
		0			1			2		
		G			G			G		
		0	1	2	0	1	2	0	1	2
B	0	950	4,219	4,074	886	4,798	4,873	1,017	4,754	4,685
	1	2,968	3,615	3,079	2,386	3,522	3,773	1,962	2,686	2,526
	2	3,206	2,921	2,618	2,021	2,800	2,812	1,490	1,715	1,840

		E								
		0			1			2		
		G			G			G		
		0	1	2	0	1	2	0	1	2
B	0	18	2,128	2,078	978	5,674	5,579	1,857	5,969	5,975
	1	1,931	2,413	2,315	2,700	3,602	3,484	2,685	3,808	3,580
	2	2,152	1,967	2,212	2,303	2,662	2,567	2,261	2,808	2,492

- Max

- Min

Table F-9. MOE 4 BDG and BEG Three-way Means

		D								
		0			1			2		
		G			G			G		
		0	1	2	0	1	2	0	1	2
B	0	5,275	8,583	8,412	5,223	9,092	9,129	5,207	9,241	9,001
	1	7,317	7,934	7,169	6,740	7,868	8,110	6.313	7,035	6,869
	2	7,557	7,217	6,936	6,371	7,154	7,166	5,861	6,088	6,218

		E								
		0			1			2		
		G			G			G		
		0	1	2	0	1	2	0	1	2
B	0	4,349	6,492	6,443	5,299	10,187	9,919	6,056	10,237	10,181
	1	6,281	6,767	6,651	7,057	7,926	7,804	7,032	8,145	7,692
	2	6,530	6,315	6,575	6,657	6,997	6,906	6,602	7,147	6,839

- Max

- Min

Table F-10. MCE 6 BDG and BEG Three-Way Means

		D=0, G=0	D=0, G=1	D=0, G=2	D=1, G=0	D=1, G=1	D=1, G=2	D=2, G=0	D=2, G=1	D=2, G=2
B	0	7,125	6,141	6,154	7,119	6,348	6,329	7,127	6,523	6,530
	1	6,975	6,119	6,051	7,067	6,913	6,886	7,073	6,995	7,059
	2	6,960	6,130	6,252	7,086	6,998	7,000	7,101	7,090	7,099

		E=0, G=0	E=0, G=1	E=0, G=2	E=1, G=0	E=1, G=1	E=1, G=2	E=2, G=0	E=2, G=1	E=2, G=2
B	0	7,140	7,001	7,010	7,130	6,200	6,164	7,100	5,811	5,838
	1	7,079	6,804	6,741	7,035	6,681	6,655	7,002	6,542	5,601
	2	7,058	6,845	6,795	7,064	6,727	6,723	7,025	6,644	6,832

(oval) - Min

(underline) - Max

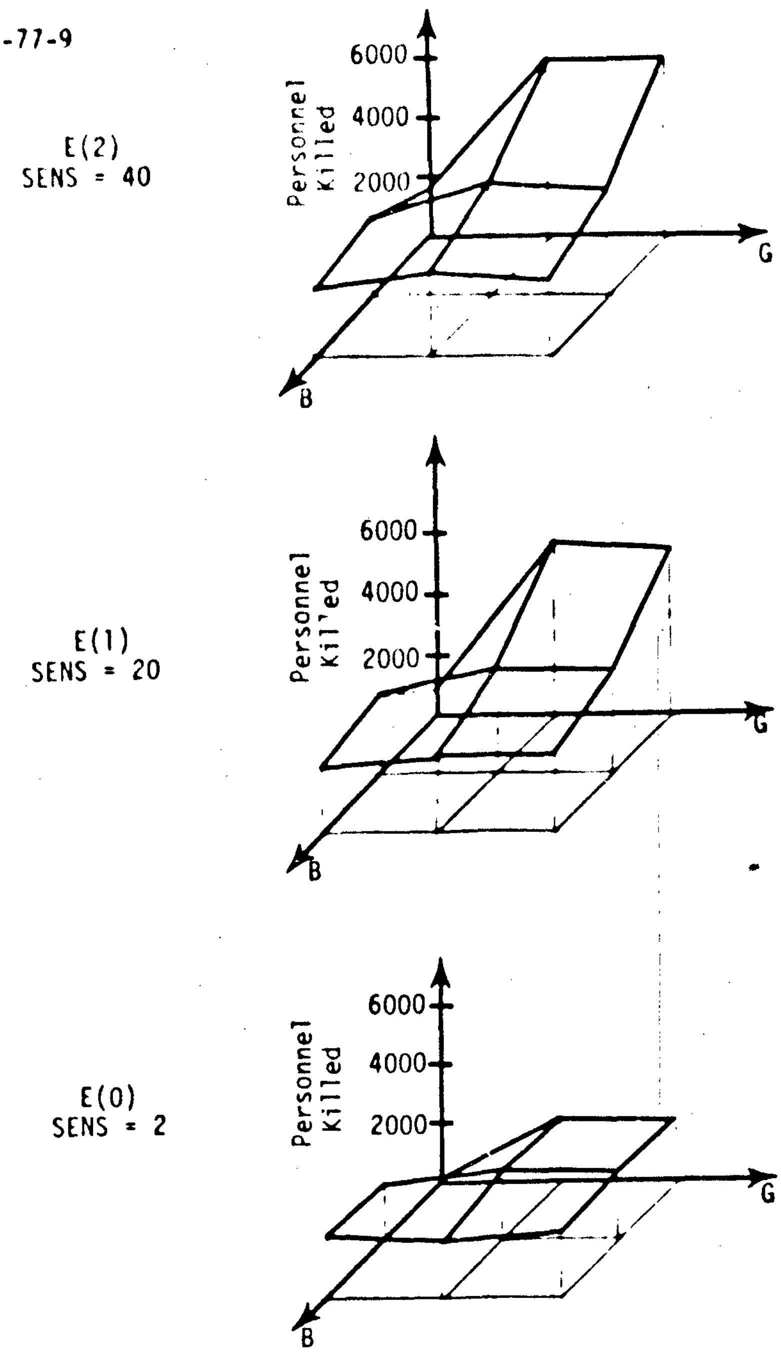

Figure F-21. MOE 2 PC/PCINT x SENS x DENTI (BEG) Interaction

E(2)
SENS = 40

E(1)
SENS = 20

E(0)
SENS = 2

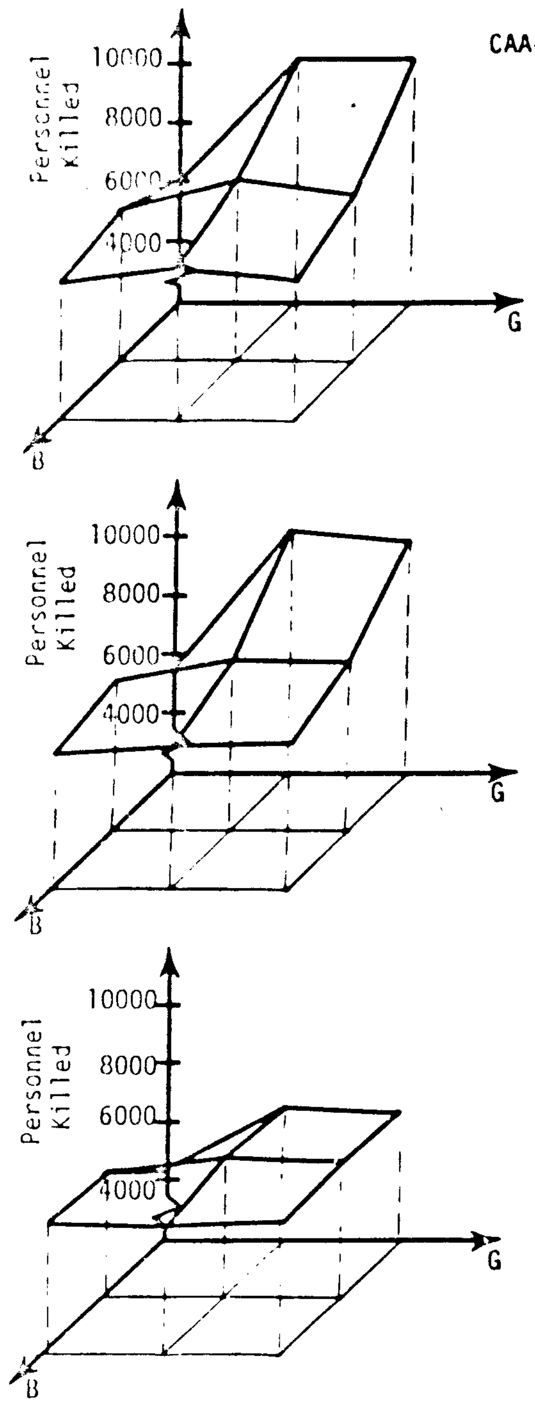

Figure F-22. MOE 4 PC/PCINT x SENS x DENTI (BE5) Interaction

E(2)
SENS = 40

E(1)
SENS = 20

E(0)
SENS = 2

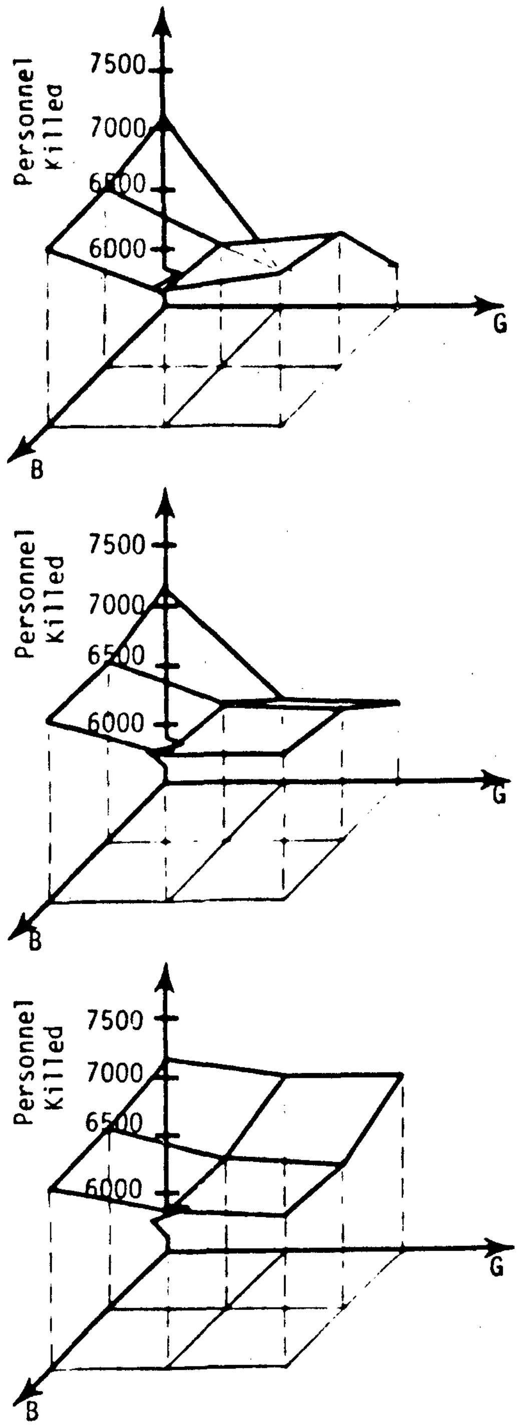

Figure F-23. MOE 6 PC/PCINT x SENS x DENTI (BEG) Interaction

APPENDIX G

WEAPON MOE

The contents of this appendix parallel the contents of Appendix F. First, marginal and two-way means, ANOVA tables, and plots of main and interaction effects are presented for the three Weapon MOE:

MOE 3 - Number of Red Weapons Killed Due to Detection

MOE 5 - Total Number of Red Weapons Killed

MOE 7 - Total Number of Blue Weapons Killed

Finally, the three-way means of PC/PCINT x SENDLA x DENTI and PC/PCINT x SENS x DENTI are given and plots of the PC/PCINT x SENS x DENTI interaction are illustrated for each of the three MOE. Discussion of the analyses of the Weapon MOE is given in Chapter 3, paragraph 3-7.

Table G-1. MOE 3, 5, and 7 Marginal Means

MOE 3 Red weapons killed due to detection

Factor	Level 0	Level 1	Level 2
A - WAIT	190	166	155
B - PC/PCINT	219	164	129
C - DELTHR	153	173	187
D - SENDLA	210	171	131
E - SENS	106	195	211
F - TYPE	192	183	138
G - DENTI	114	200	198

MOE 5 Total Red weapons killed

Factor	Level 0	Level 1	Level 2
A - WAIT	3,789	3,774	3,759
B - PC/PCINT	3,814	3,771	3,737
C - DELTHR	3,779	3,754	3,789
D - SENDLA	3,819	3,771	3,732
E - SENS	3,716	3,794	3,811
F - TYPE	3,787	3,789	3,745
G - DENTI	3,712	3,807	3,803

MOE 7 Total Blue weapons killed

Factor	Level 0	Level 1	Level 2
A - WAIT	1,380	1,391	1,403
B - PC/PCINT	1,347	1,404	1,424
C - DELTHR	1,529	1,377	1,269
D - SENDLA	1,324	1,414	1,436
E - SENS	1,437	1,385	1,352
F - TYPE	1,406	1,378	1,390
G - DENTI	1,462	1,352	1,360

Table G-2. MOE 3 Two-way Means
(Red weapons killed due to detection)

		B		
		0	1	2
	0	219	187	164
A	1	220	165	114
	2	217	141	109
			D	
	0	247	185	138
A	1	202	164	132
	2	180	163	124
			F	
	0	224	205	142
A	1	190	177	132
	2	162	166	139
			C	
	0	207	230	218
B	1	145	165	183
	2	106	123	158
			E	
	0	91	263	302
B	1	119	185	189
	2	109	136	142
			G	
	0	51	299	306
B	1	149	168	176
	2	141	133	113
			E	
	0	95	177	186
C	1	109	205	205
	2	115	202	243
			G	
	0	82	186	190
C	1	115	189	215
	2	145	225	190
			F	
	0	260	206	163
D	1	177	195	141
	2	138	148	109
			F	
	0	90	118	111
E	1	224	208	153
	2	261	223	149
			G	
	0	109	237	230
F	1	141	206	201
	2	91	157	164

	C		
	0	1	2
	184	174	213
A	142	176	181
	132	169	165
		E	
	117	214	239
A	101	194	204
	100	176	191
		G	
	128	217	226
A	107	203	189
	107	180	180
		D	
	225	226	205
B	209	167	117
	196	119	72
		F	
	246	210	199
B	188	184	121
	141	154	92
		D	
	218	139	101
C	193	186	139
	218	187	154
		F	
	174	159	125
C	193	179	146
	209	209	141
		E	
	153	234	242
D	100	198	214
	66	151	177
		G	
	153	243	233
D	104	202	207
	84	155	155
		G	
	83	116	120
E	122	231	231
	136	254	243

Table G-3. MOE 5 Two-way Means
(Total Red weapons killed)

		B				C		
		0	1	2		0	1	2
	0	3,815	3,767	3,764		3,804	3,755	3,806
A	1	3,818	3,776	3,728	A	3,774	3,758	3,790
	2	3,808	3,750	3,719		3,760	3,749	3,769
			D				E	
	0	3,845	3,778	3,743		3,726	3,808	3,832
A	1	3,817	3,770	3,735	A	3,710	3,795	3,817
	2	3,797	3,763	3,718		3,711	3,781	3,785
			F				G	
	0	3,812	3,805	3,749		3,720	3,822	3,824
A	1	3,789	3,793	3,740	A	3,710	3,811	3,801
	2	3,760	3,770	3,747		3,705	3,788	3,785
			C				D	
	0	3,822	3,800	3,819		3,832	3,817	3,792
B	1	3,774	3,753	3,786	B	3,824	3,766	3,723
	2	3,741	3,709	3,761		3,802	3,729	3,680
			E				F	
	0	3,696	3,852	3,894		3,830	3,813	3,798
B	1	3,731	3,789	3,793	B	3,784	3,795	3,734
	2	3,721	3,743	3,747		3,747	3,760	3,704
			G				D	
	0	3,652	3,692	3,897		3,838	3,768	3,731
B	1	3,748	3,782	3,783	C	3,790	3,760	3,711
	2	3,735	3,746	3,731		3,829	3,783	3,753
			E				F	
	0	3,733	3,799	3,805		3,796	3,789	3,753
C	1	3,693	3,782	3,786	D	3,763	3,766	3,733
	2	3,721	3,801	3,844		3,802	3,813	3,751
			G				E	
	0	3,706	3,817	3,814		3,765	3,842	3,851
C	1	3,690	3,775	3,797	D	3,708	3,791	3,813
	2	3,738	3,828	3,799		3,675	3,750	3,770
			F				G	
	0	3,846	3,329	3,783		3,750	3,860	3,848
D	1	3,774	3,792	3,746	D	3,702	3,804	3,806
	2	3,740	3,747	3,708		3,682	3,757	3,756
			F				G	
	0	3,698	3,727	3,723		3,682	3,732	3,734
E	1	3,815	3,814	3,754	E	3,720	3,832	3,831
	2	3,847	3,827	3,760		3,732	3,856	3,846
			G					
	0	3,707	3,836	3,818				
F	1	3,738	3,816	3,814				
	2	3,690	3,768	3,778				

Table G-4. MOE 7 Two-way Means
(Total Blue weapons killed)

		B		
		0	1	2
A	0	1,329	1,394	1,416
	1	1,347	1,412	1,415
	2	1,364	1,405	1,441
		D		
A	0	1,314	1,393	1,433
	1	1,318	1,415	1,441
	2	1,342	1,432	1,436
		F		
A	0	1,375	1,377	1,387
	1	1,413	1,377	1,383
	2	1,431	1,379	1,399
		C		
B	0	1,491	1,309	1,240
	1	1,536	1,404	1,272
	2	1,561	1,417	1,294
		E		
B	0	1,456	1,329	1,256
	1	1,424	1,404	1,383
	2	1,432	1,423	1,417
		G		
B	0	1,477	1,279	1,285
	1	1,450	1,383	1,378
	2	1,460	1,395	1,416
		E		
C	0	1,564	1,528	1,494
	1	1,421	1,366	1,340
	2	1,326	1,259	1,221
		G		
C	0	1,608	1,495	1,484
	1	1,444	1,342	1,344
	2	1,336	1,219	1,251
		F		
D	0	1,375	1,286	1,312
	1	1,412	1,408	1,421
	2	1,433	1,439	1,437
		F		
E	0	1,462	1,427	1,423
	1	1,397	1,376	1,383
	2	1,360	1,331	1,365
		G		
F	0	1,462	1,374	1,383
	1	1,457	1,328	1,349
	2	1,468	1,355	1,347

	C		
	0	1	2
	1,524	1,366	1,249
A	1,524	1,379	1,271
	1,539	1,386	1,286
	E		
	1,440	1,369	1,329
A	1,434	1,382	1,356
	1,438	1,404	1,369
	G		
	1,461	1,337	1,341
A	1,459	1,354	1,361
	1,468	1,365	1,378
	D		
	1,316	1,344	1,381
B	1,316	1,439	1,456
	1,342	1,458	1,472
	F		
	1,348	1,350	1,343
B	1,424	1,379	1,409
	1,447	1,406	1,418
	D		
	1,435	1,567	1,585
C	1,323	1,393	1,414
	1,215	1,282	1,310
	F		
	1,547	1,519	1,522
C	1,392	1,367	1,372
	1,281	1,248	1,277
	E		
	1,379	1,317	1,277
D	1,466	1,400	1,375
	1,467	1,438	1,404
	G		
	1,452	1,251	1,271
D	1,469	1,385	1,387
	1,467	1,421	1,421
	G		
	1,470	1,429	1,413
E	1,466	1,339	1,351
	1,452	1,289	1,315

Table G-5. MOE 3 ANOVA

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-ratio
A	2	51,149	25,574	7.93***
B	2	330,133	165,066	51.17***
C	2	47,411	23,705	7.35***
D	2	248,985	124,493	38.59***
E	2	515,423	257,712	79.88***
F	2	136,285	68,143	21.12***
G	2	394,583	197,291	61.16***
AB	4	28,267	7,067	2.19
AC	4	22,314	5,578	1.73
AD	4	24,212	6,053	1.88
AE	4	7,828	1,957	<1.00
AF	4	24,421	6,105	1.89
AG	4	7,817	1,954	<1.00
BC	4	18,313	4,578	1.42
BD	4	82,753	20,688	6.42***
BE	4	269,492	67,373	20.88***
BF	4	29,022	7,255	2.25
BG	4	766,678	191,669	59.41***
CD	4	46,223	11,556	3.58**
CE	4	16,427	4,107	1.27
CF	4	10,955	2,739	<1.00
CG	4	42,580	10,645	3.30*
DE	4	6,428	1,607	<1.00
DF	4	54,727	13,682	4.24**
DG	4	9,188	2,297	<1.00
EF	4	126,452	31,613	9.80***
EG	4	69,354	17,338	5.37***
FG	4	43,651	10,913	3.38*
R	144	464,549	3,226	
Total	242	3,895,617		

*-Significant at the 0.05-level of significance.

**-Significant at the 0.01-level of significance.

***-Significant at the 0.001-level of significance.

Table G-6. MOE 5 ANOVA

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-ratio
A	2	34,966	17,483	8.15***
B	2	240,111	120,056	55.97***
C	2	52,092	26,046	12.14***
D	2	312,918	156,459	72.94***
E	2	419,275	209,637	97.73***
F	2	98,399	49,200	22.94***
G	2	473,224	236,612	110.30***
AB	4	16,402	4,100	1.91
AC	4	12,981	3,245	1.51
AD	4	8,338	2,085	<1.00
AE	4	9,376	2,344	1.09
AF	4	19,799	4,950	2.31
AG	4	5,492	1,373	<1.00
BC	4	7,829	1,957	<1.00
BD	4	52,827	13,207	6.16***
BE	4	244,452	61,113	28.49***
BF	4	18,415	4,604	2.15
BG	4	609,990	152,498	71.09***
CD	4	13,891	3,473	1.62
CE	4	22,884	5,721	2.67*
CF	4	7,934	1,984	<1.00
CG	4	27,263	6,816	3.18*
DE	4	3,152	788	<1.00
DF	4	12,434	3,109	1.45
DG	4	11,812	2,953	1.38
EF	4	94,577	23,644	11.02***
EG	4	50,633	12,658	5.90***
FG	4	25,462	6,366	2.97*
R	144	308,896	2,145	
Total	242	3,215,821		

*
**   } See Table G-5
***

Table G-7. MOE 7 ANOVA

Source of variation	Degree of freedom	Sum of squares	Mean square	F-ratio
A	2	22,760	11,380	3.44*
B	2	259,744	129,872	39.23***
C	2	2,771,368	1,385,684	418.52***
D	2	566,649	283,324	85.57***
E	2	300,541	150,271	45.39***
F	2	33,234	16,617	5.02**
G	2	615,384	307,692	92.93***
AB	4	9,552	2,388	<1.00
AC	4	4,818	1,205	<1.00
AD	4	11,663	2,916	<1.00
AE	4	16,342	4,085	1.23
AF	4	26,452	6,613	2.00
AG	4	7,298	1,825	<1.00
BC	4	34,833	8,708	2.63*
BD	4	82,830	20,707	6.25***
BE	4	278,841	69,710	21.05***
BF	4	21,832	5,458	1.65
BG	4	218,111	54,528	16.47***
CD	4	44,389	11,097	3.35*
CE	4	10,714	2,678	<1.00
CF	4	5,701	1,425	<1.00
CG	4	16,158	4,040	1.22
DE	4	15,585	3,896	1.18
DF	4	81,411	20,353	6.15***
DG	4	210,032	52,508	15.86***
EF	4	15,824	3,956	1.19
EG	4	108,142	27,036	8.17***
FG	4	19,421	4,855	1.47
R	144	476,776	3,311	
Total	242	6,286,402		

*, **, *** See Table G-5

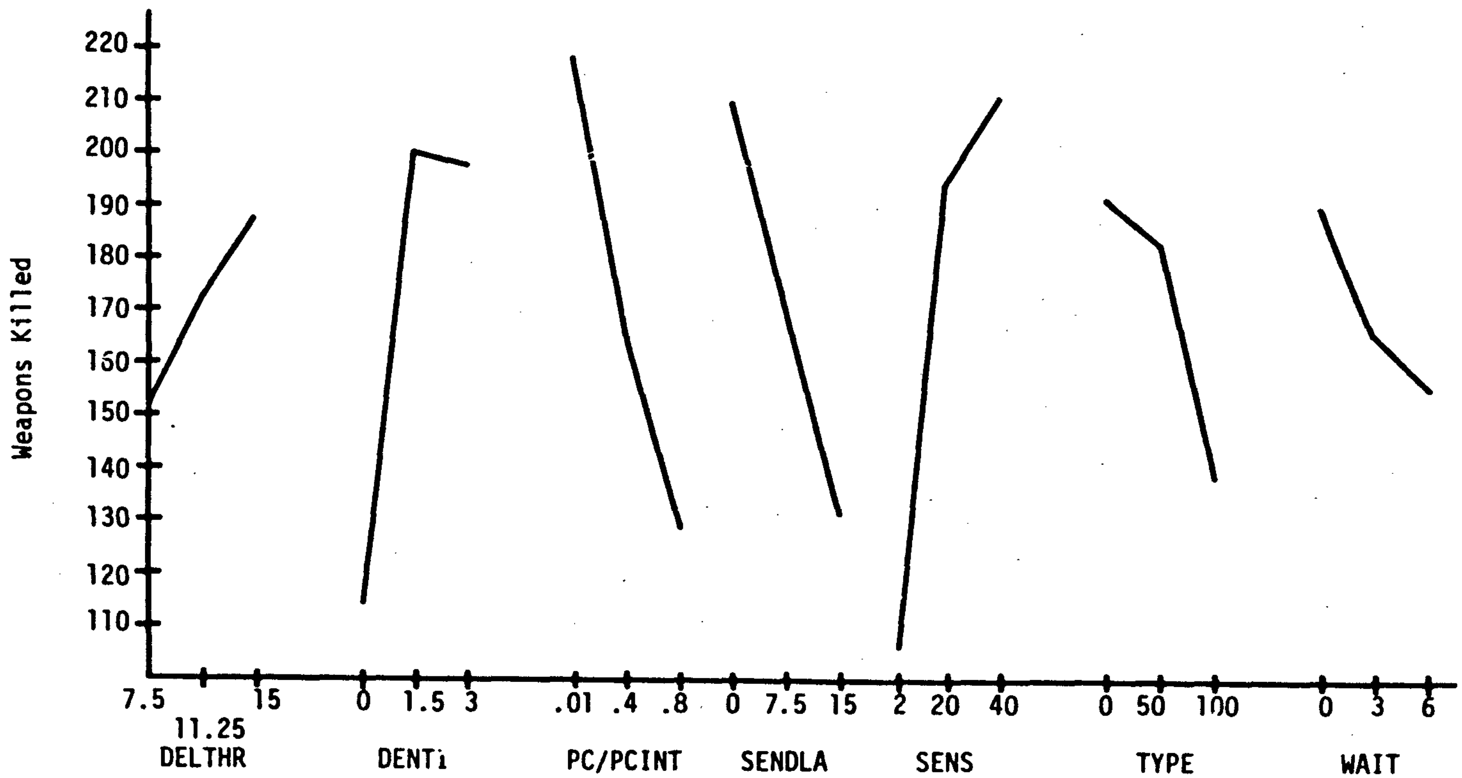

Figure G-1. MOE 3 Main Effects - Red Weapons Killed Due to Detection

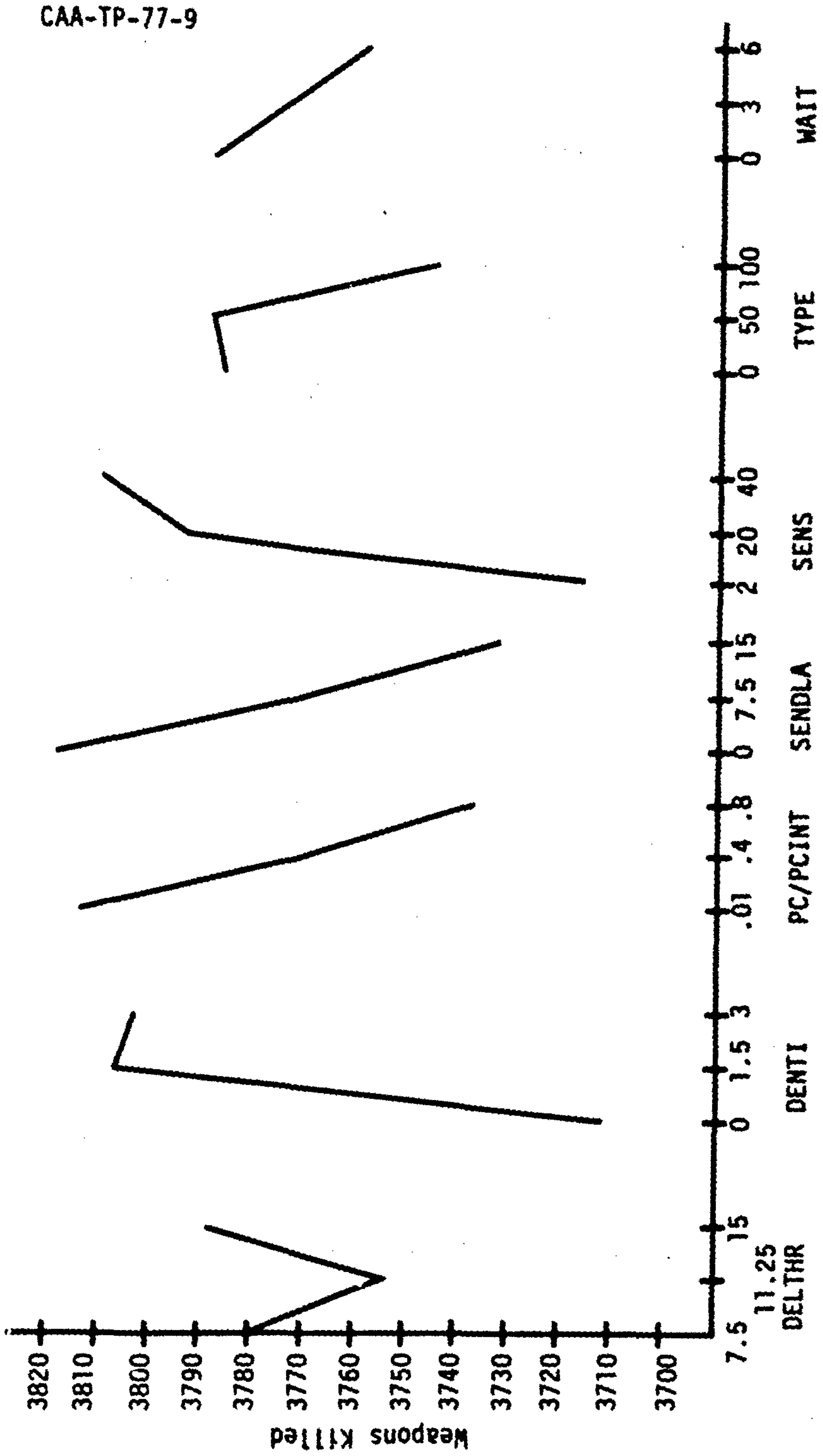

Figure G-2. MOE 5 Main Effects - Total Red Weapons Killed

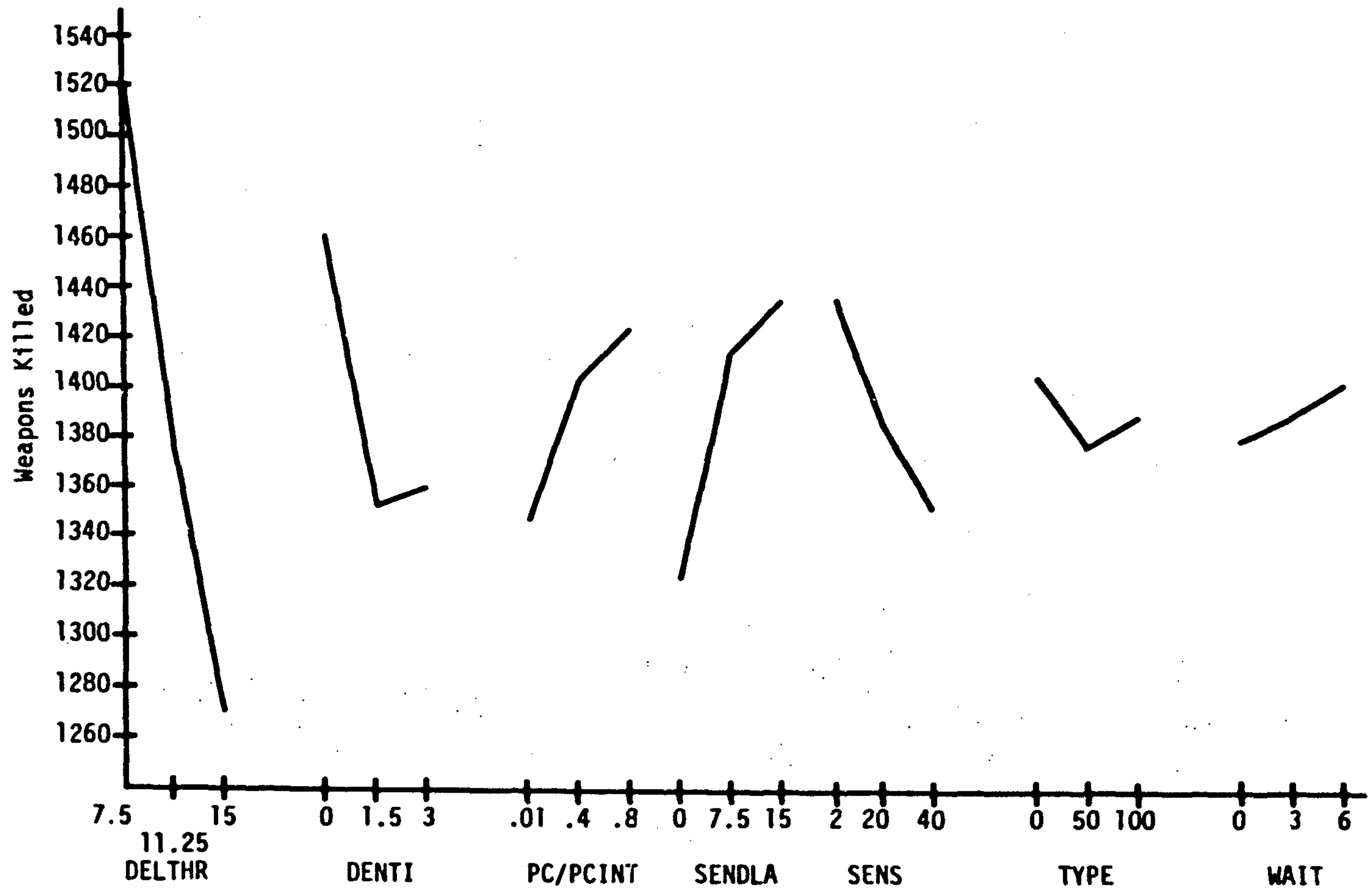

Figure G-3. MOE 7 Main Effects - Total Blue Weapons Killed

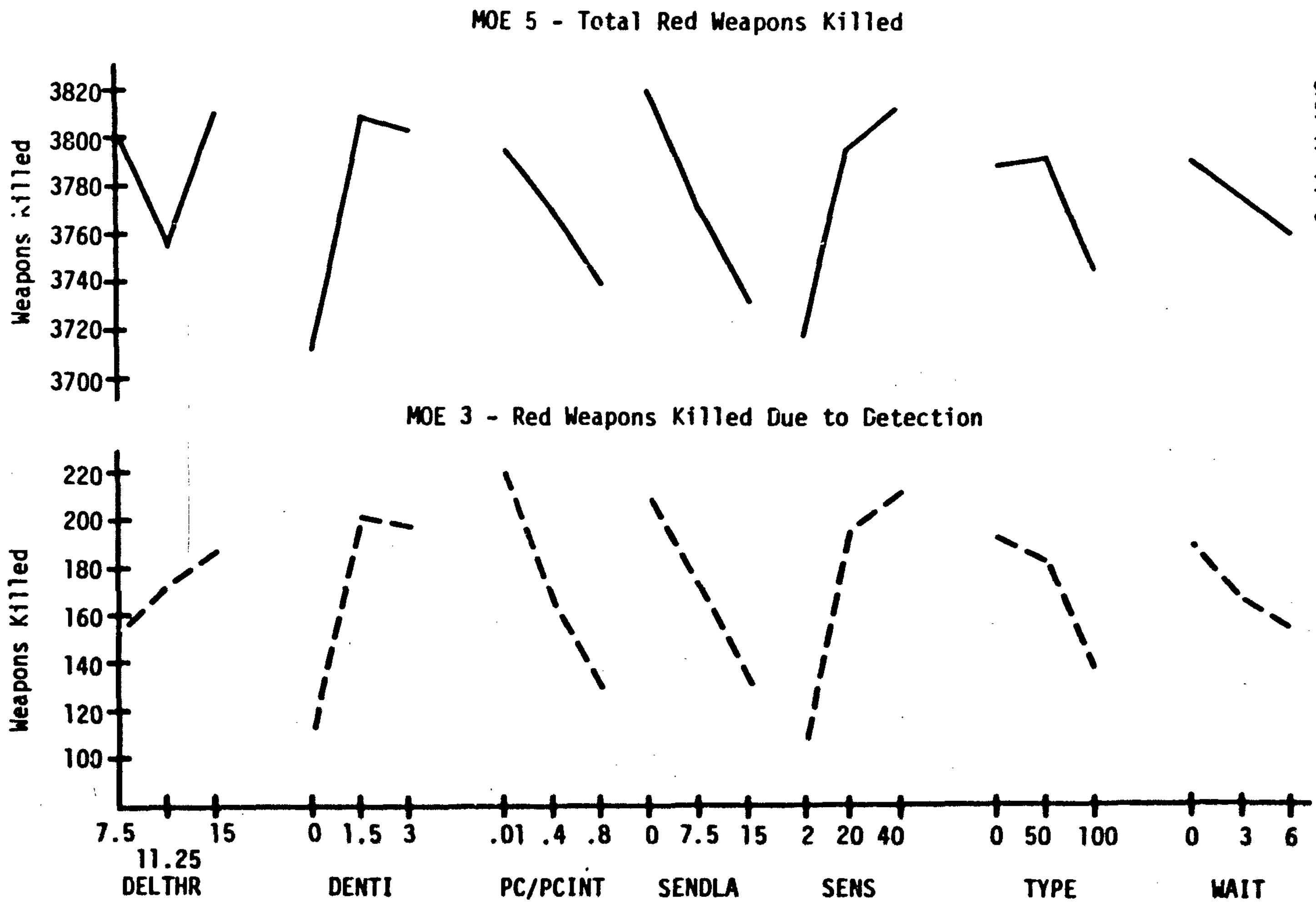

Figure G-4. MOE 3 and MOE 5 Main Effects

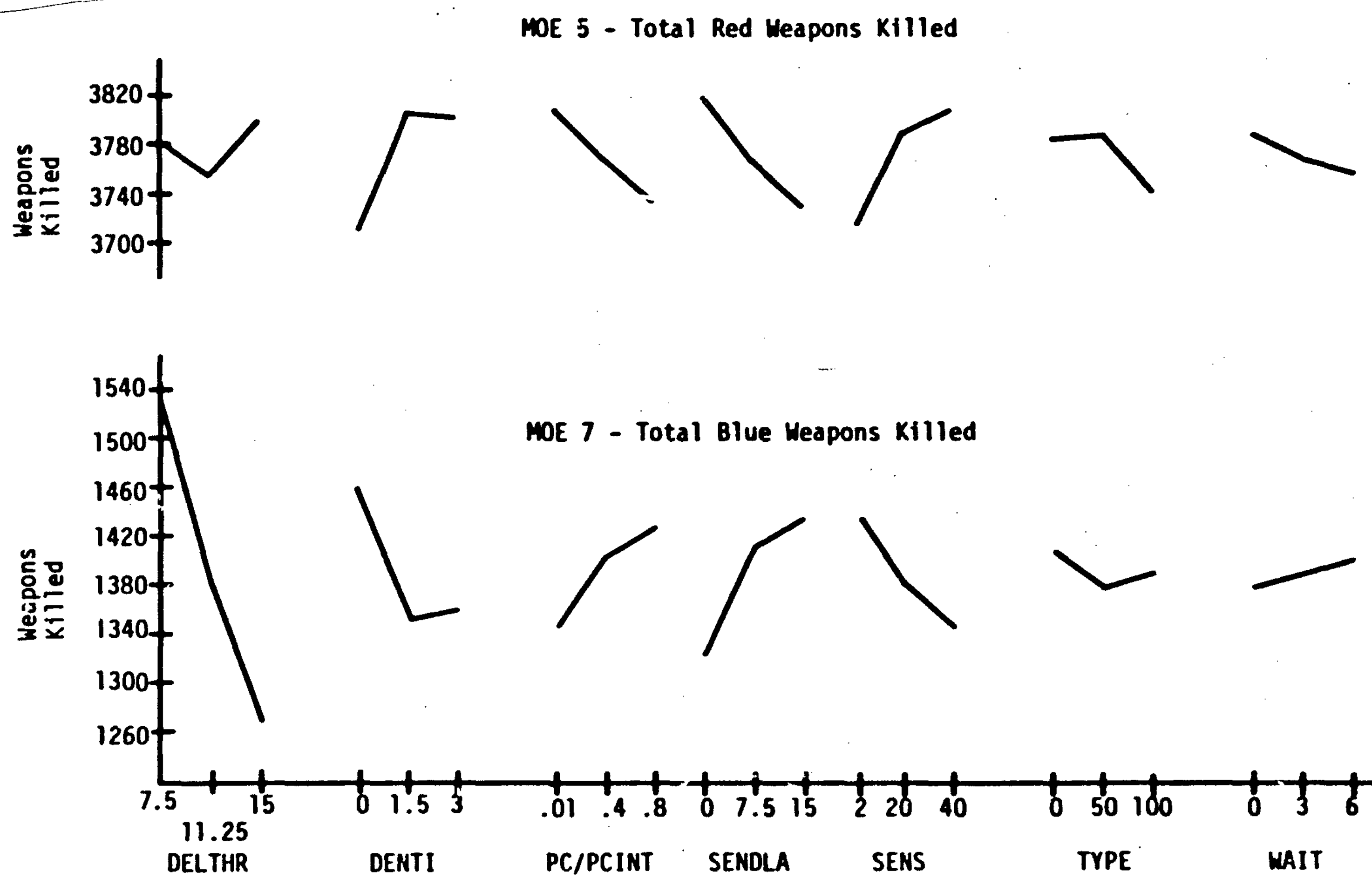

Figure G-5. MOE 5 and MOE 7 Main Effects

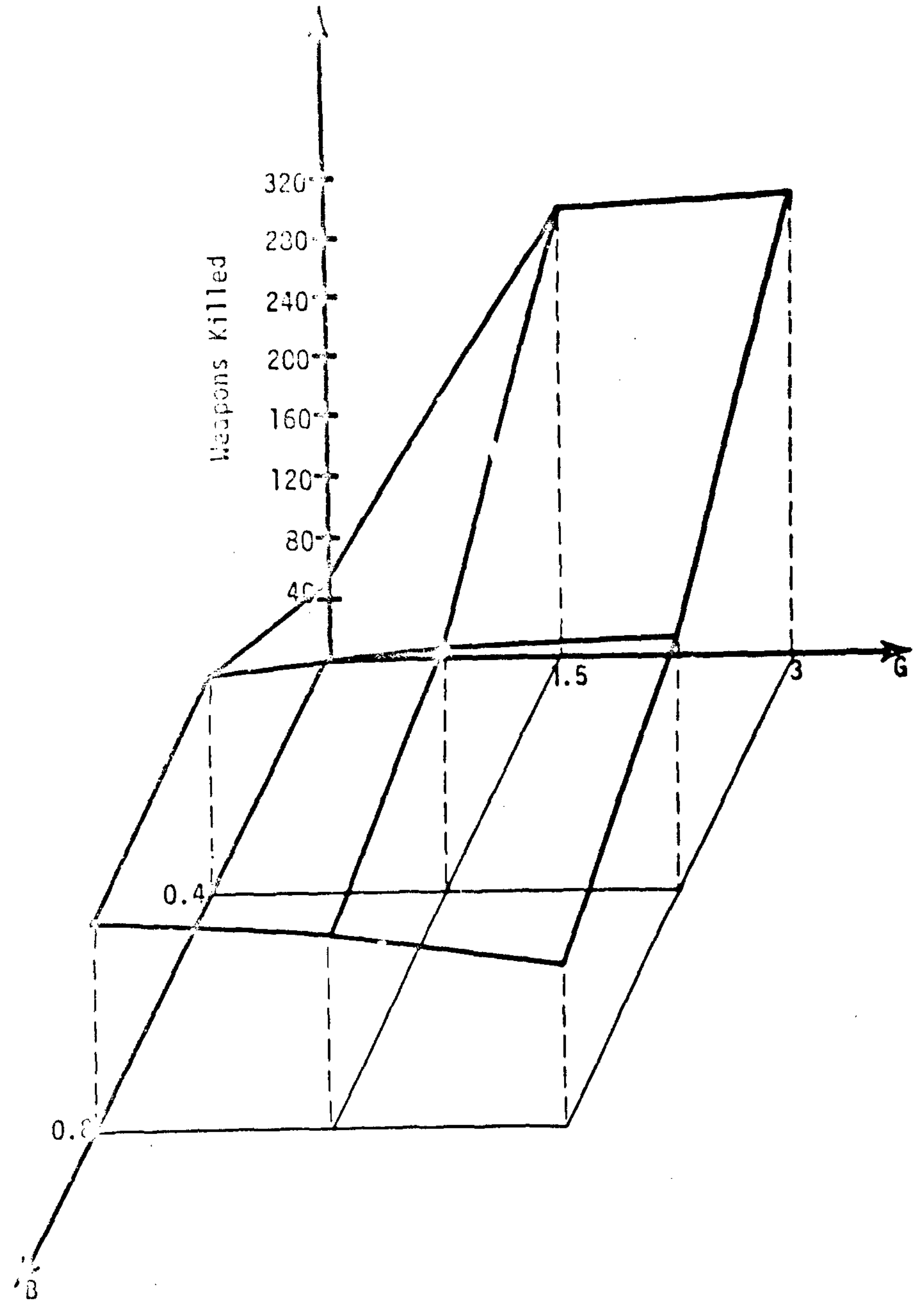

Figure G-6. MOE 3 PC/PCINT x DENTI (BG) Interaction

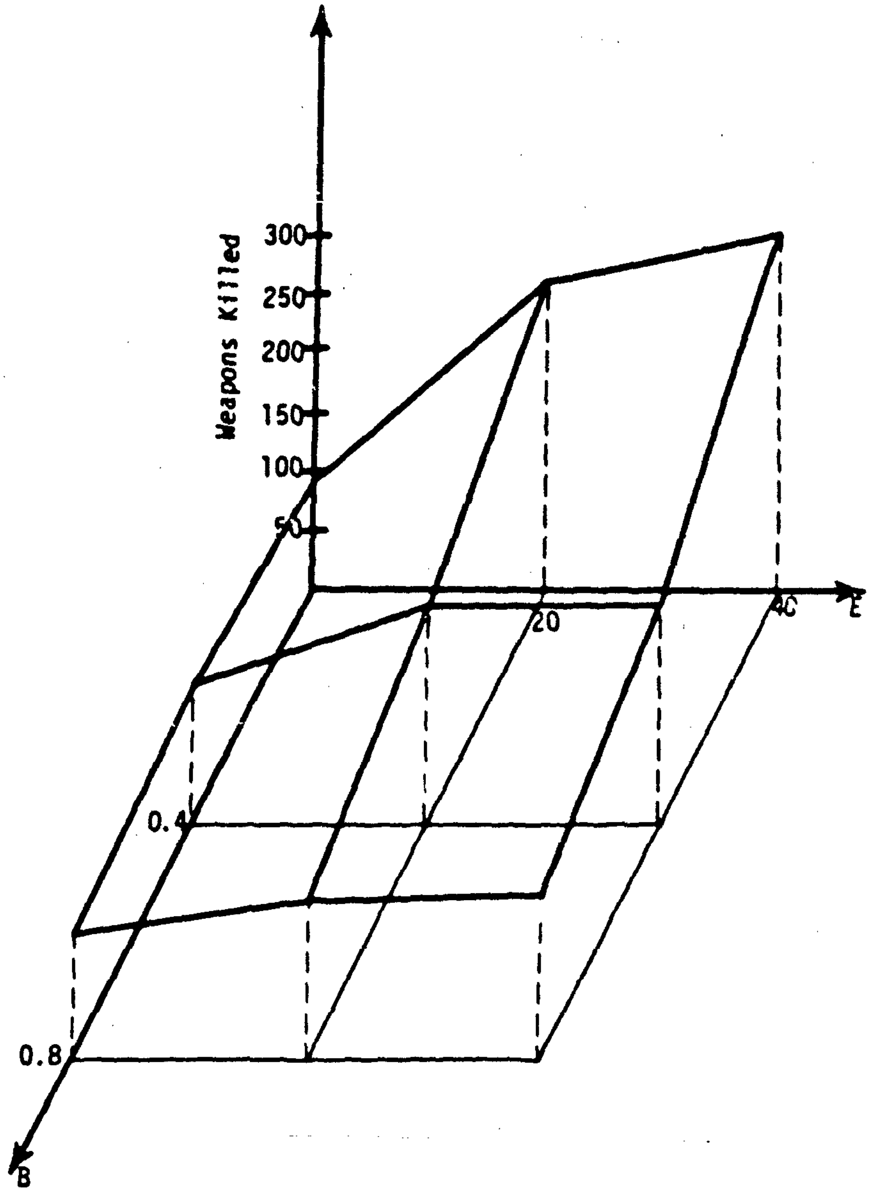

Figure G-7. MOE 3 PC/PCINT x SENS (BE) Interaction

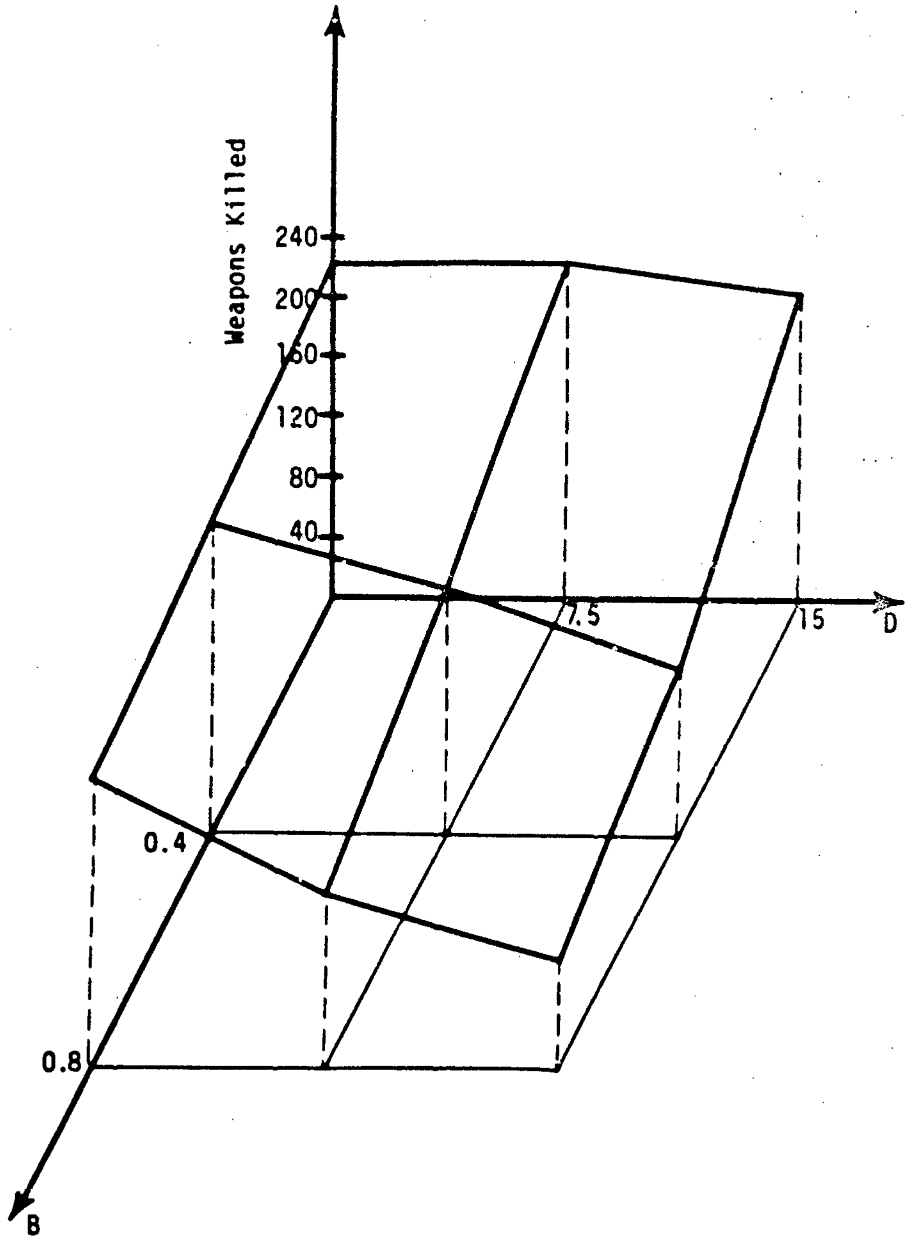

Figure G-8. MOE 3 PC/PCINT x SENDLA (BD) Interaction

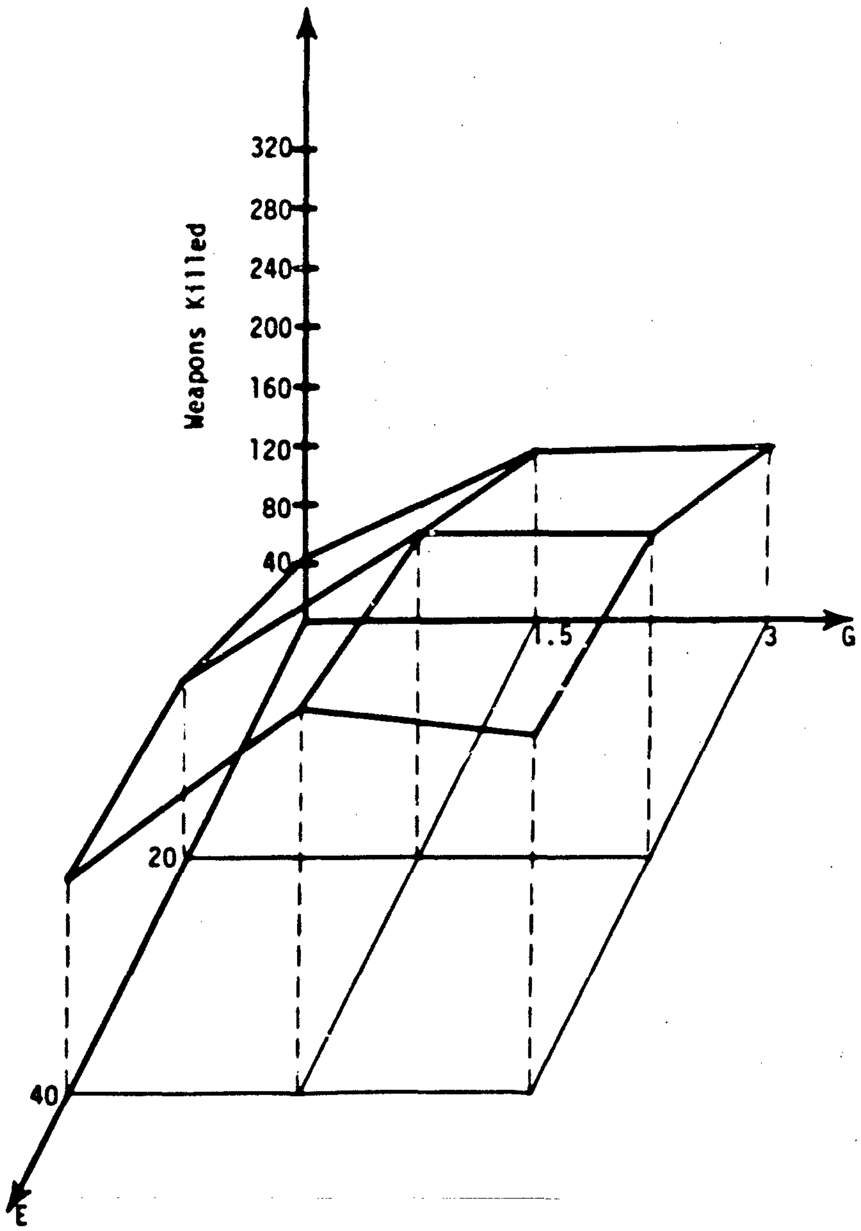

Figure G-9. MUE 3 SENS x DENTI (EG) Interaction

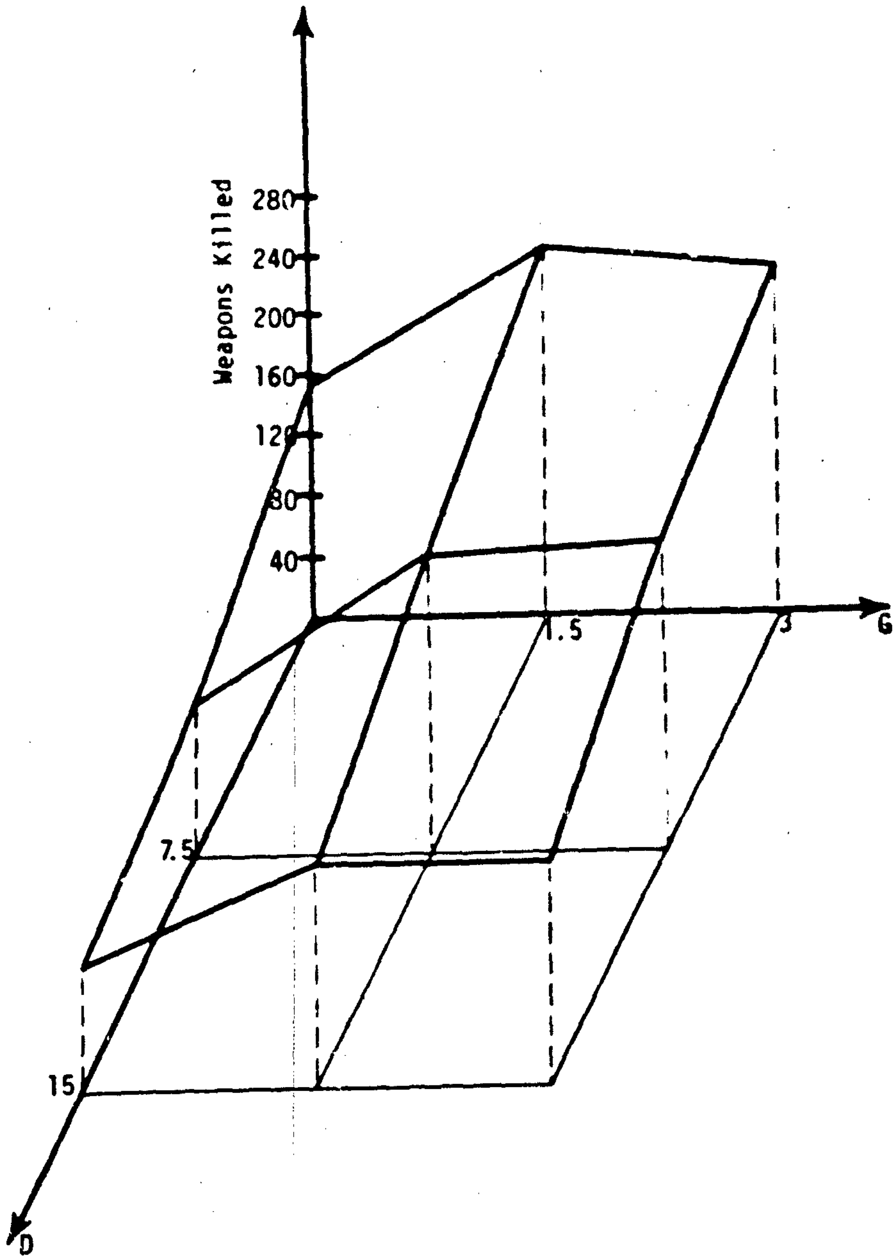

Figure G-10. MOE 3 SENDLA x DENTI (DG) Interaction

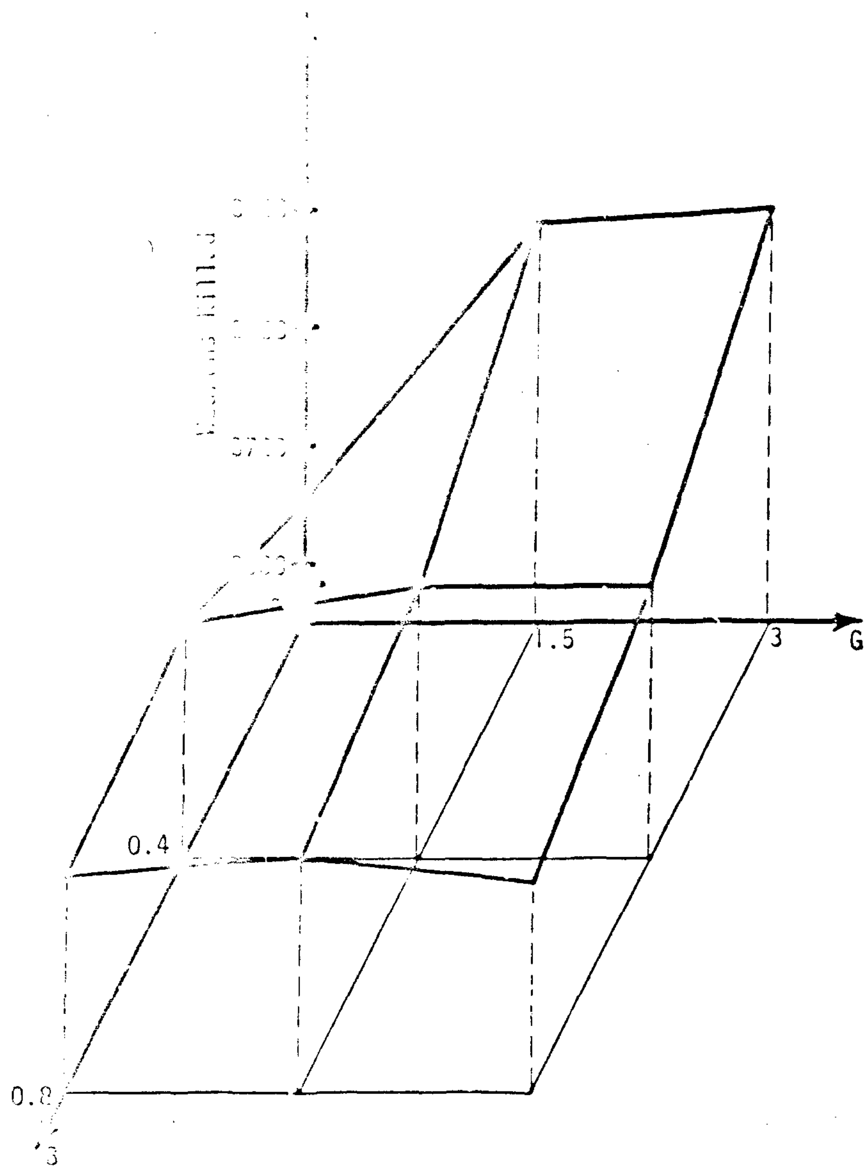

Figure G-11. MOE 5 PC/PCINT x DENTI (BG) Interaction

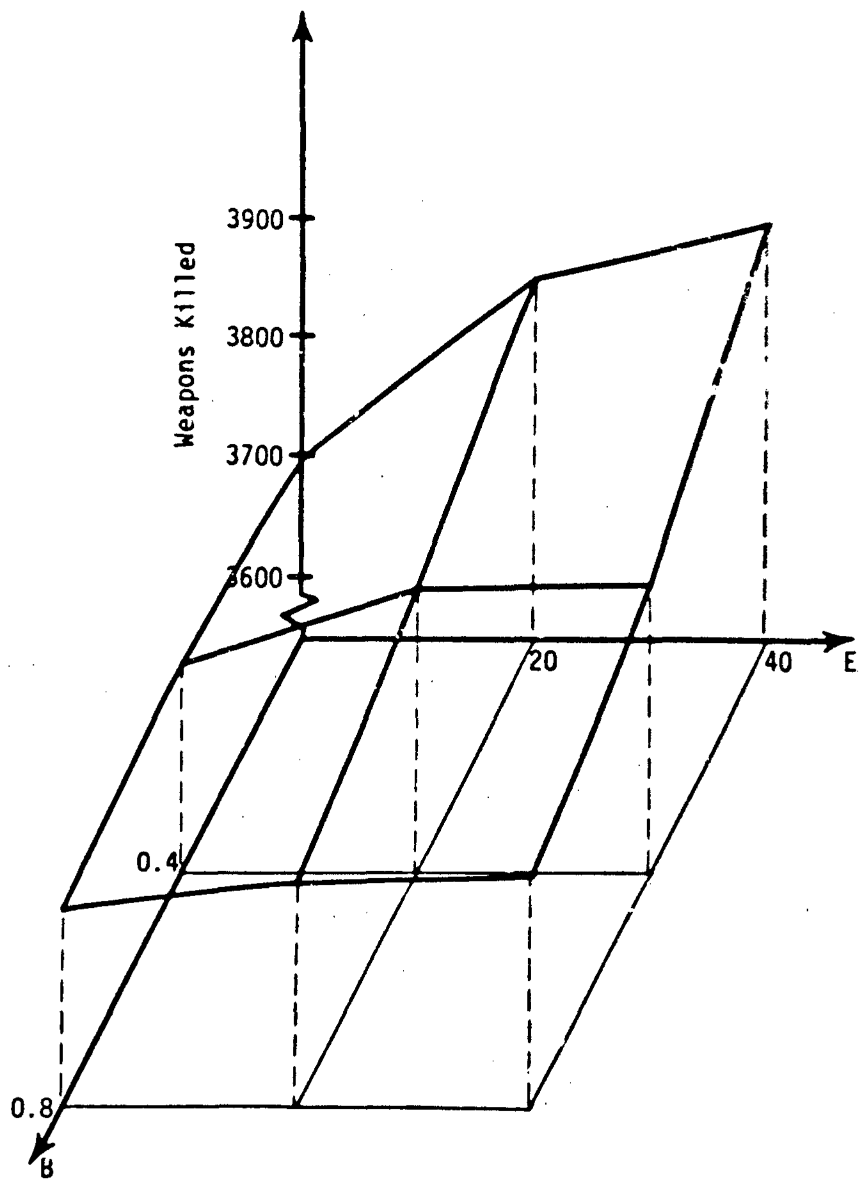

Figure G-12. MOE 5 PC/PCINT x SENS (BE) Interaction

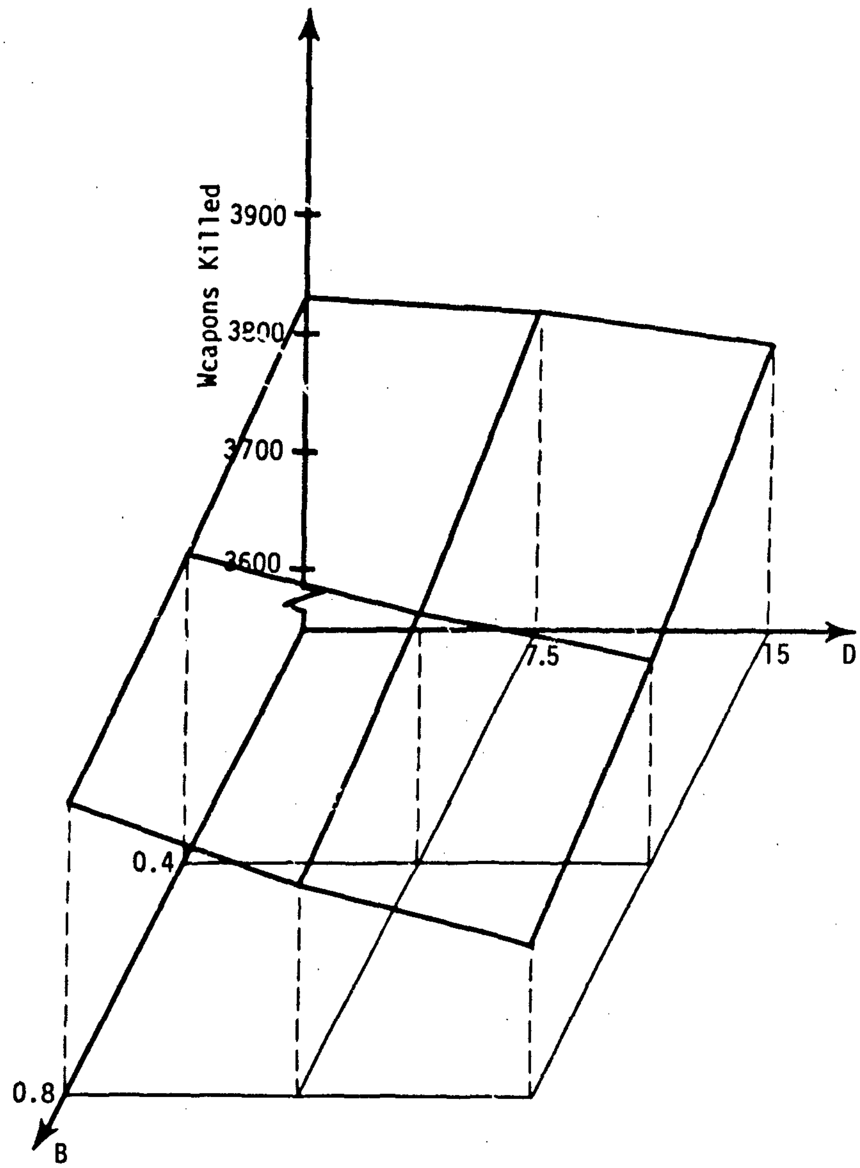

Figure G-13.. MOE 5 PC/PCINT x SENDLA (BD) Interaction

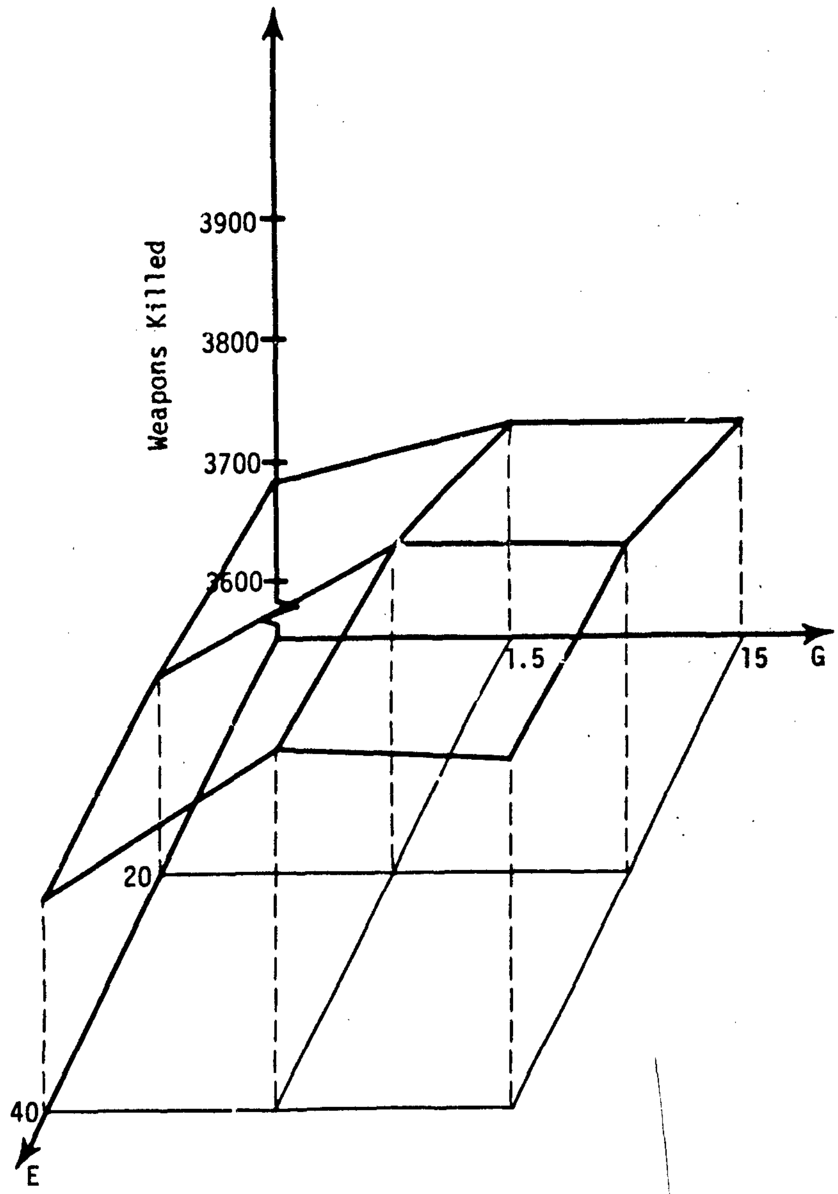

Figure G-14. MOE 5 SENS x DENTI (EG) Interaction

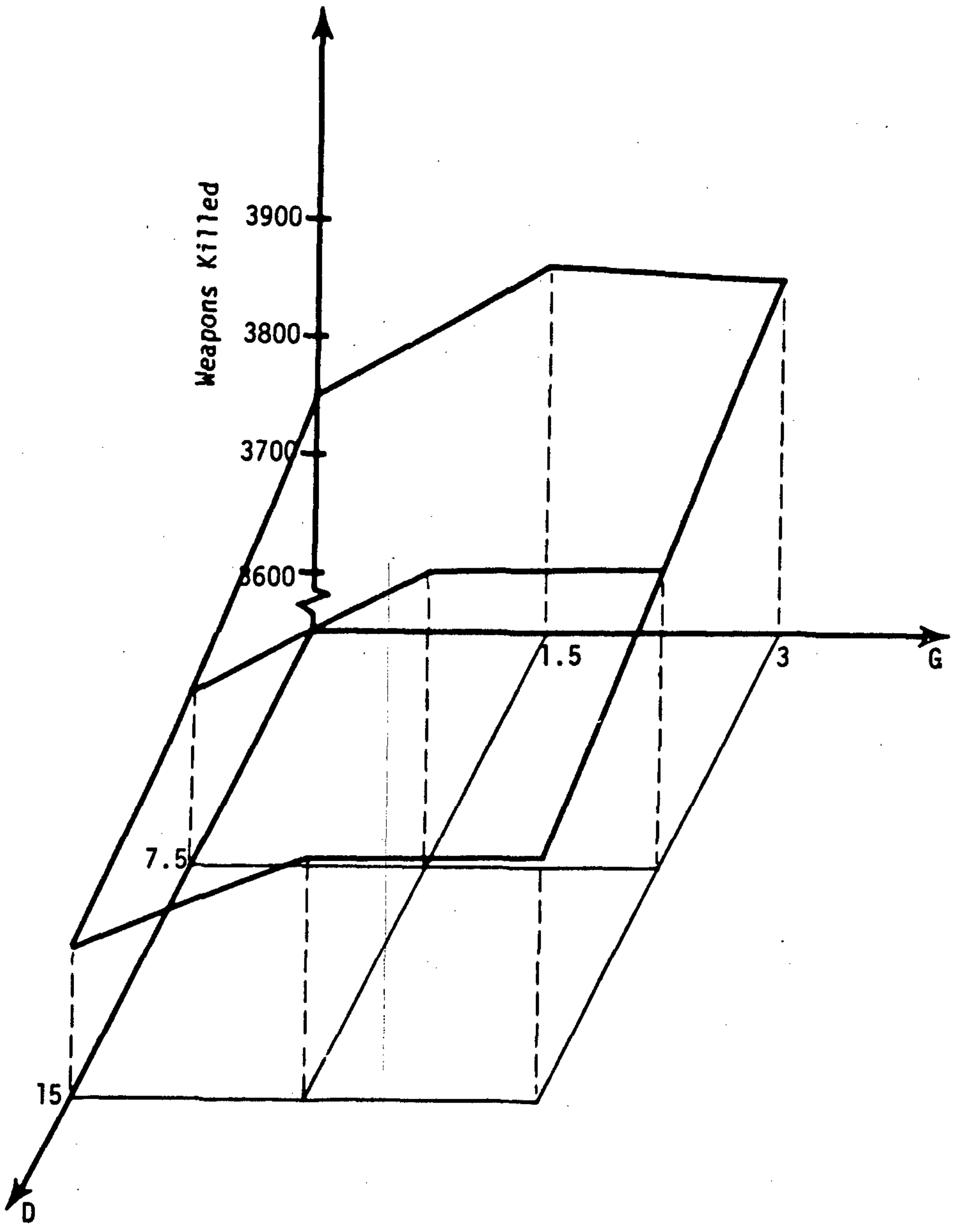

Figure G-15. MOE 5 SENDLA x DENTI (DG) Interaction

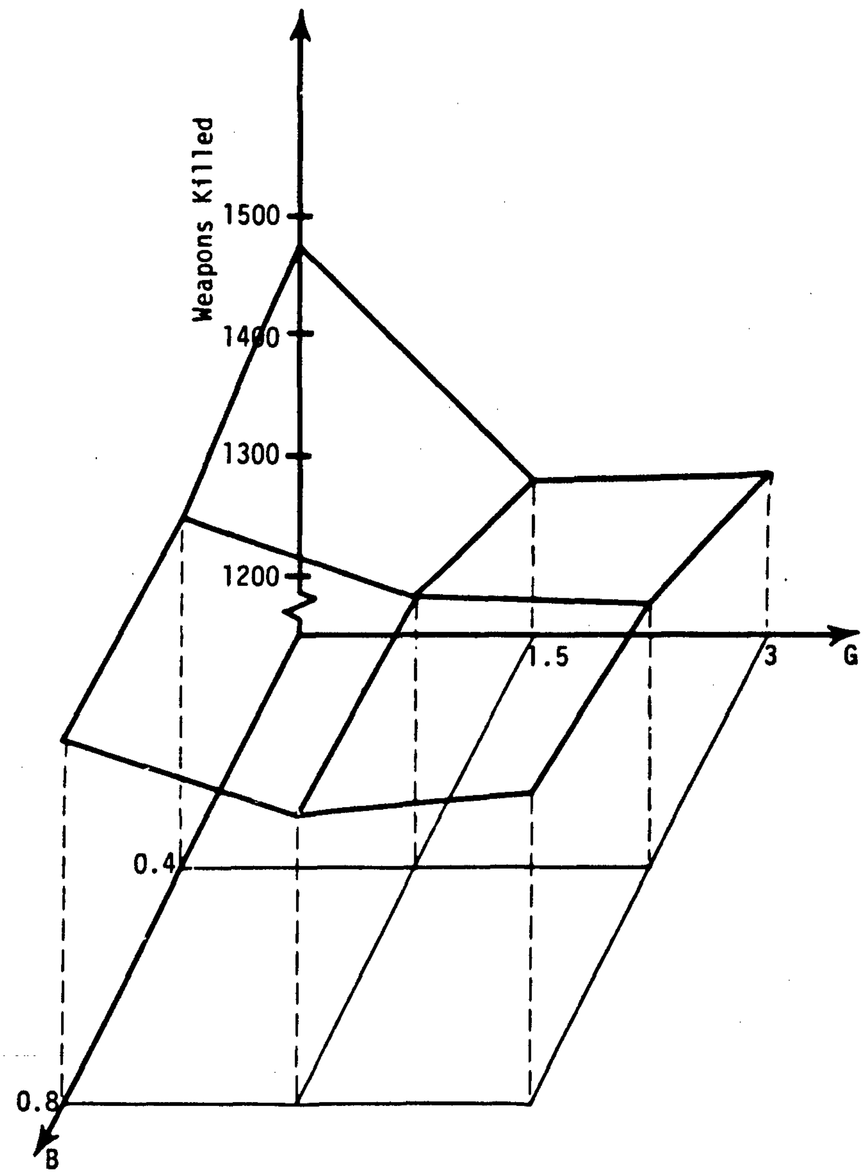

Figure G-16. MOE 7 PC/PCINT x DENTI (BG) Interaction

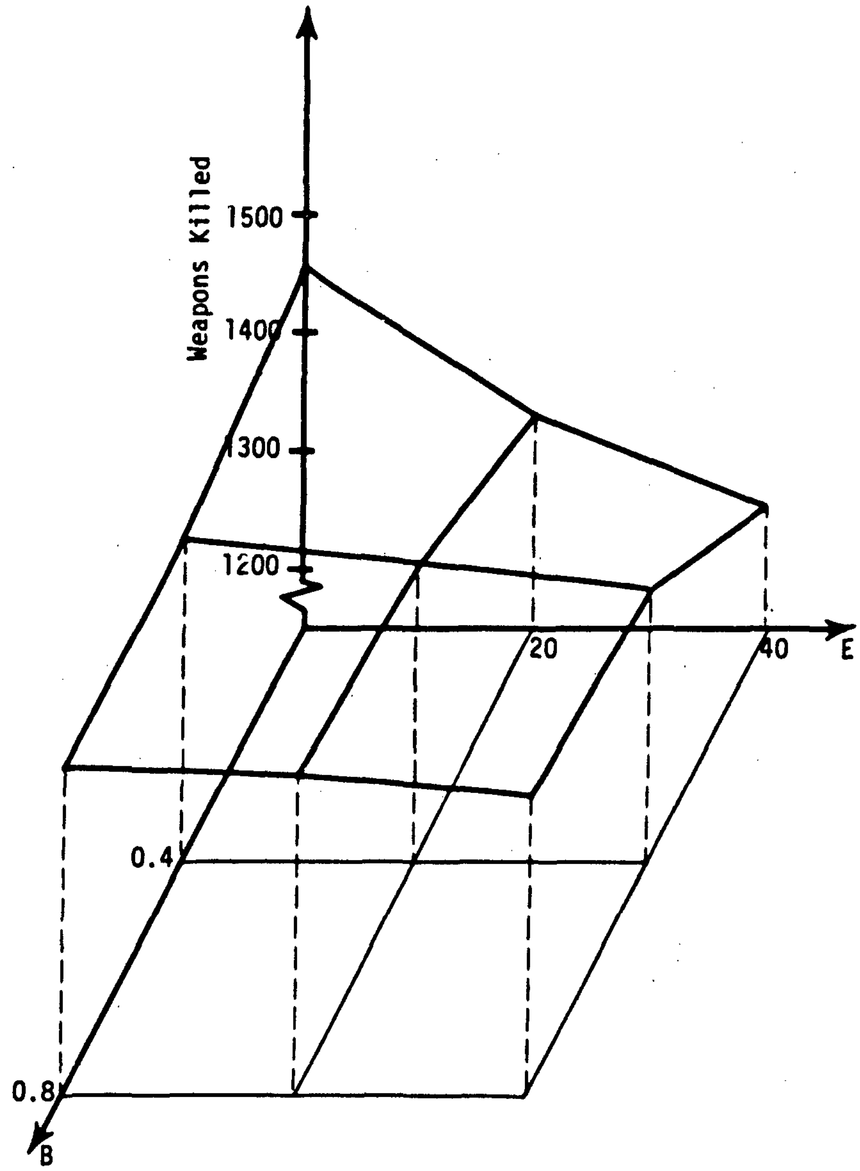

Figure G-17. MOE 7 PC/PCINT x SENS (BF) Interaction

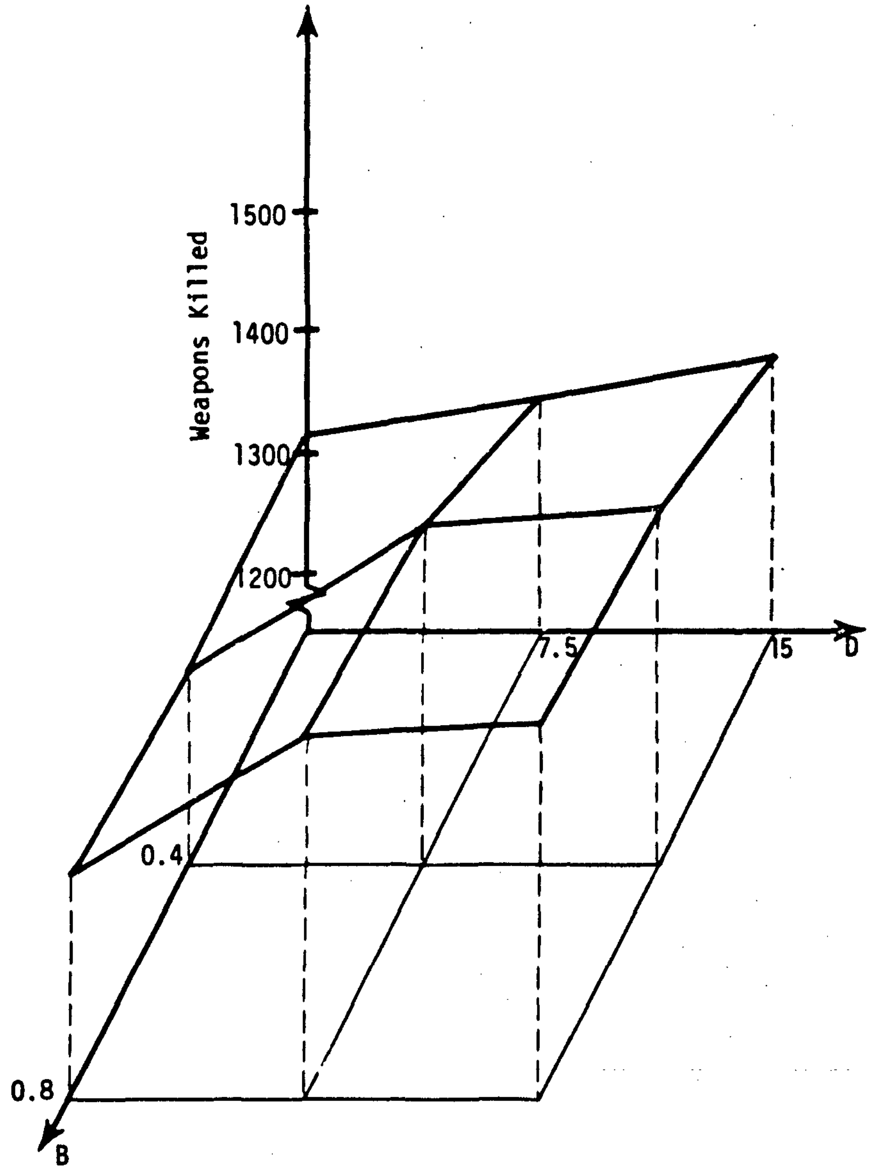

Figure G-18. MOE 7 PC/PCINT x SENDLA (BD) Interaction

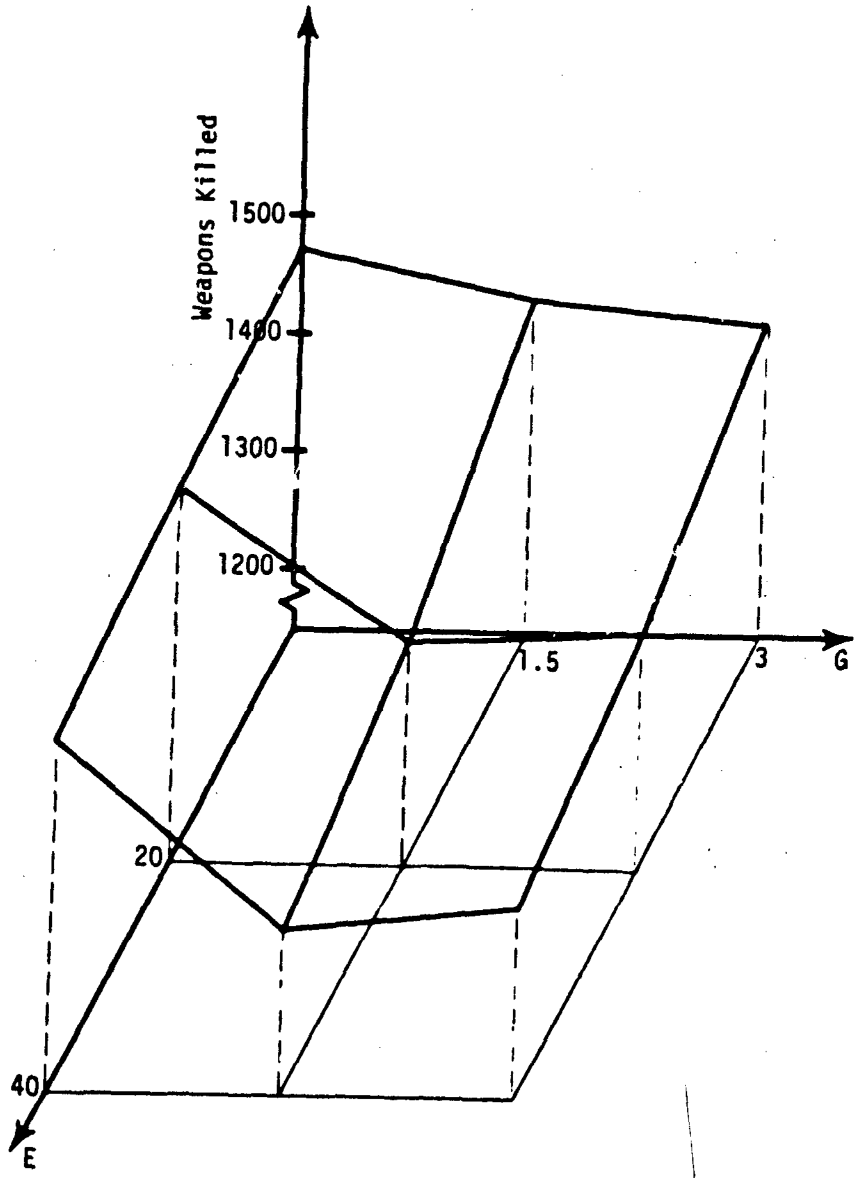

Figure G-19. MOE 7 SENS x DENTI (EG) Interaction

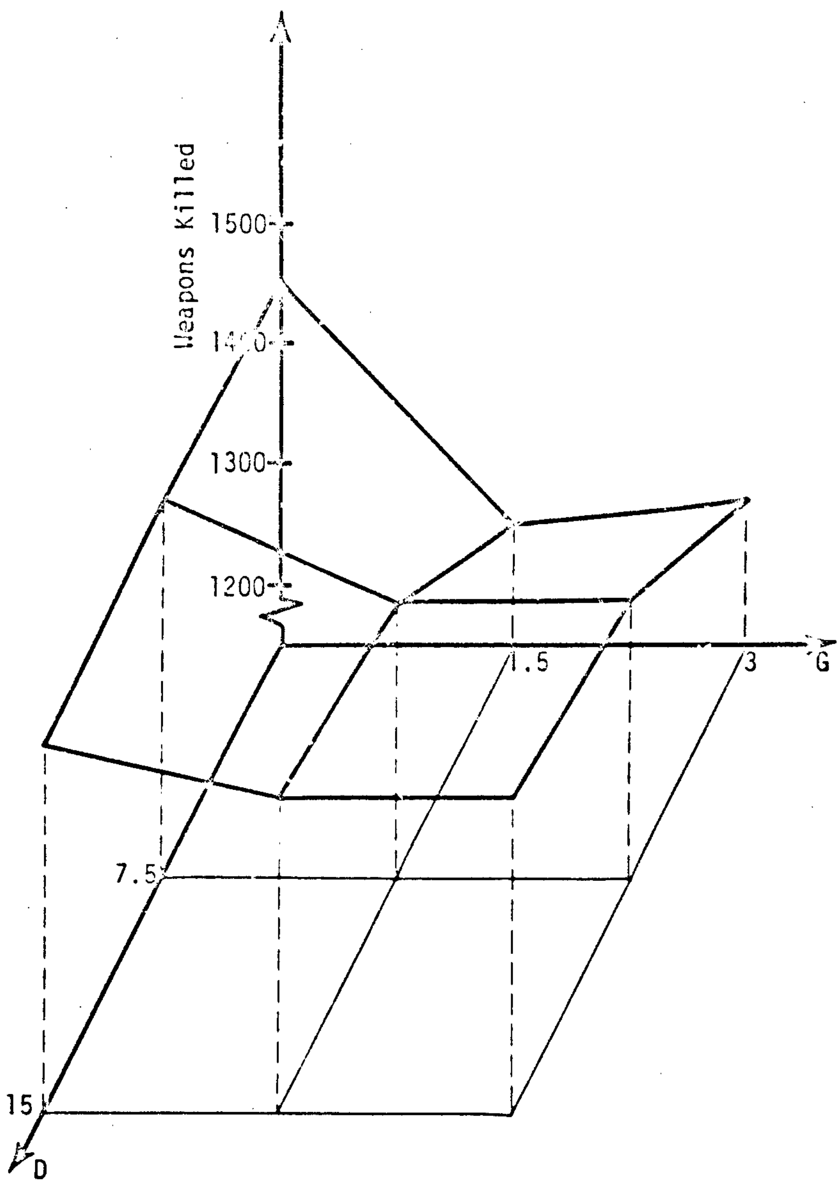

Figure G-20. MOE 7 SENDLA x DENTI (DG) Interaction

Table G-8. MOE 3 BDG and BEG Three-way Means

D

		D=0, G=0	D=0, G=1	D=0, G=2	D=1, G=0	D=1, G=1	D=1, G=2	D=2, G=0	D=2, G=1	D=2, G=2
B	0	53	298	322	51	316	312	48	283	283
	1	179	215	233	146	170	185	124	118	110
	2	227	215	145	115	119	123	80	65	72

E

		E=0, G=0	E=0, G=1	E=0, G=2	E=1, G=0	E=1, G=1	E=1, G=2	E=2, G=0	E=2, G=1	E=2, G=2
B	0	1	134	137	51	363	375	101	401	406
	1	115	119	122	174	184	197	159	200	209
	2	131	94	102	143	145	121	148	160	116

- Max

- Min

Table G-9. MOE 5 BDG and BEG Three-way Means

		D								
		0			1			2		
		G			G			G		
		0	1	2	0	1	2	0	1	2
B	0	3,654	3,914	3,927	3,652	3,900	3,899	3,650	3,863	3,864
	1	3,787	3,843	3,842	3,740	3,771	3,787	3,716	3,733	3,719
	2	3,809	3,822	3,776	3,714	3,740	3,732	3,682	3,675	3,684

		E								
		0			1			2		
		G			G			G		
		0	1	2	0	1	2	0	1	2
B	0	3,603	3,738	3,746	3,651	3,949	3,955	3,703	3,990	3,989
	1	3,713	3,748	3,733	3,771	3,791	3,804	3,760	3,807	3,812
	2	3,731	3,711	3,722	3,740	3,755	3,734	3,734	3,772	3,736

- Max

- Min

Table G-10. MOE 7 BDG and BEG Three-way Means

	D								
	0			1			2		
	G			G			G		
B	0	1	2	0	1	2	0	1	2
0	1,476	1,228	1,243	1,479	1,266	1,287	1,476	1,341	1,325
1	1,438	1,262	1,248	1,460	1,435	1,421	1,453	1,451	1,465
2	1,442	1,261	1,322	1,468	1,453	1,454	1,471	1,471	1,473

	E								
	0			1			2		
	G			G			G		
B	0	1	2	0	1	2	0	1	2
0	1,482	1,453	1,432	1,485	1,240	1,261	1,463	1,142	1,162
1	1,467	1,412	1,395	1,449	1,385	1,378	1,436	1,352	1,362
2	1,462	1,422	1,412	1,463	1,390	1,415	1,456	1,373	1,421

(oval) - Min

(underline) - Max

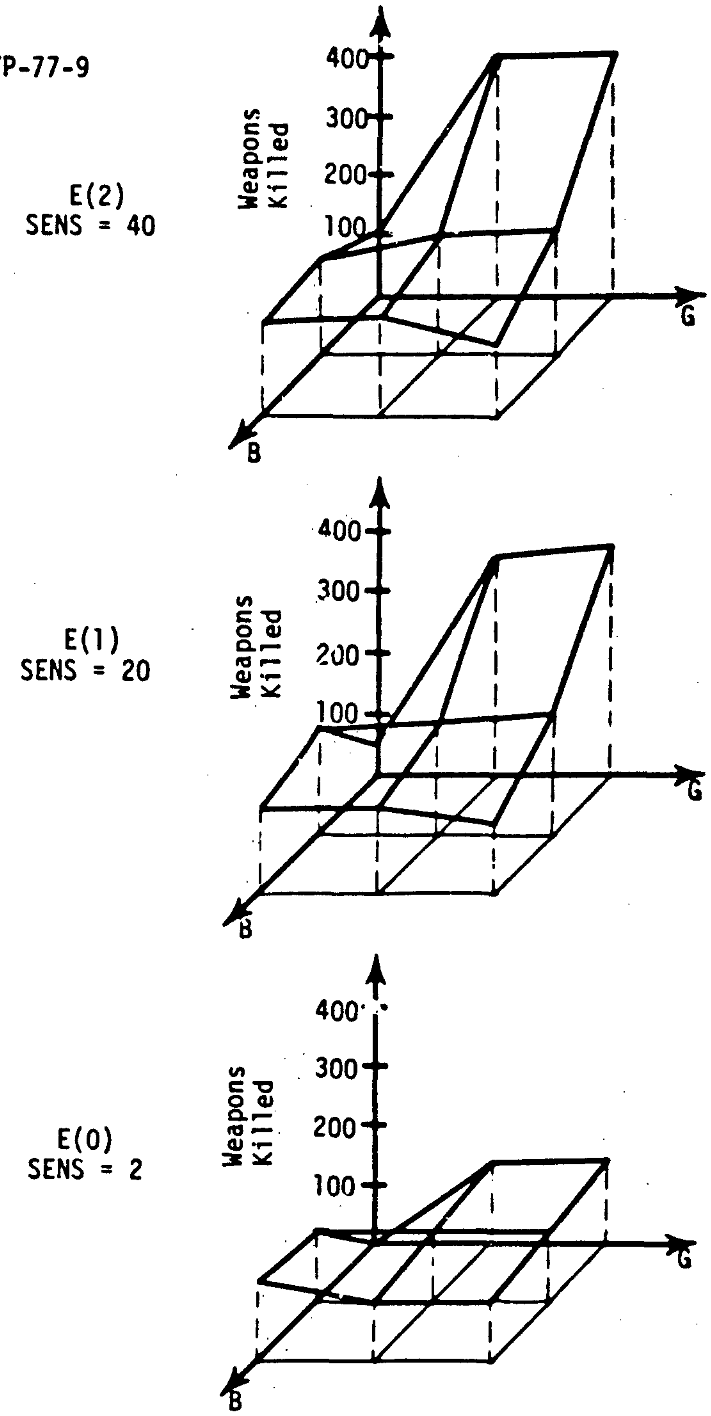

Figure G-21. MOE 3 PC/PCINT x SENS x DENTI (BEG) Interaction

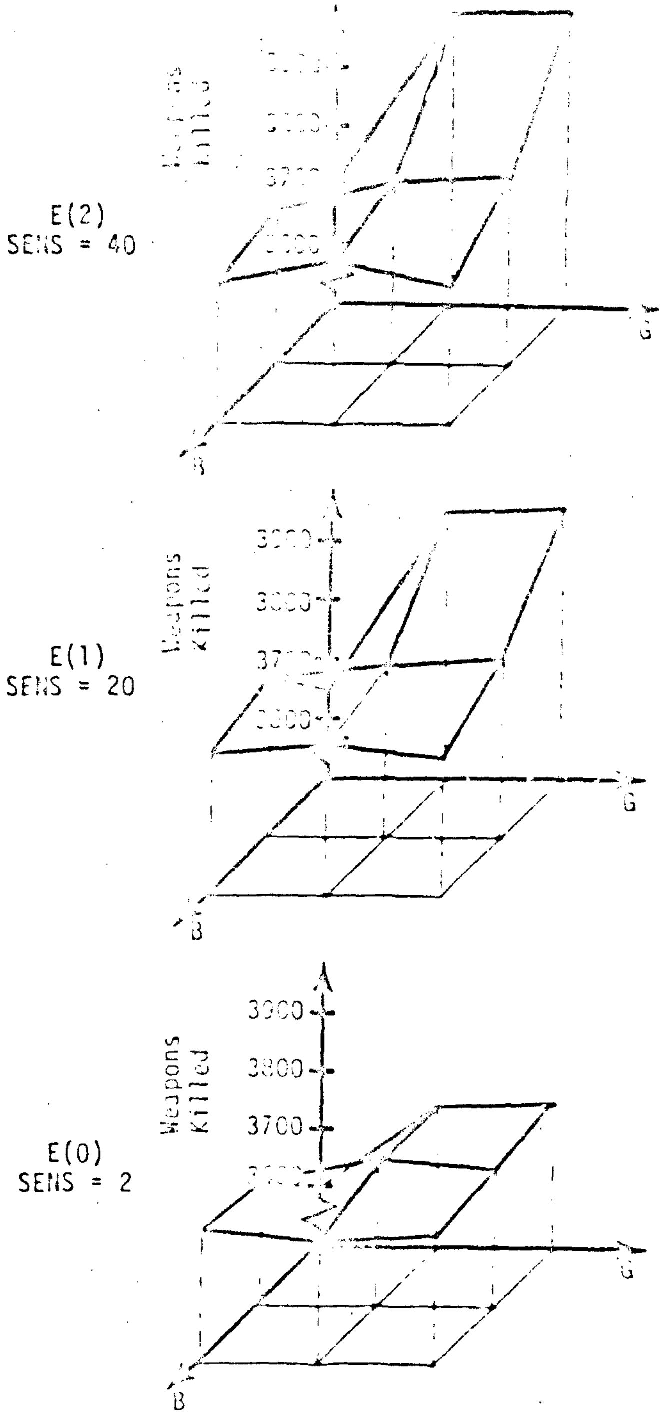

Figure G-22. MOE 5 PC/PCINT x SENS x DENTI (BEG) Interaction

E(2)
SENS = 40

E(1)
SENS = 20

E(0)
SENS = 2

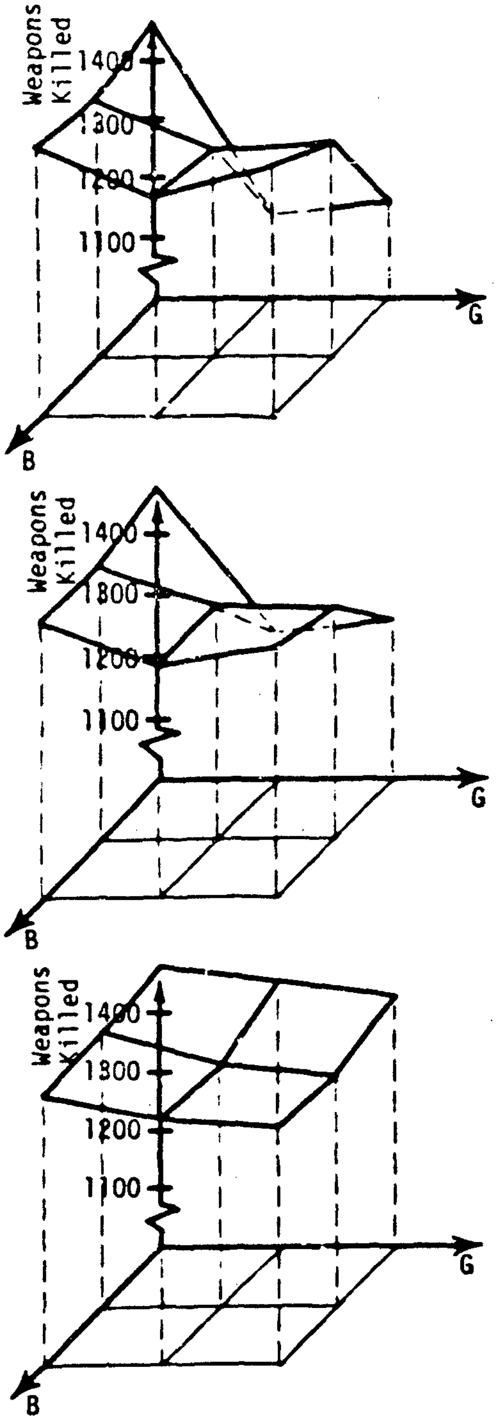

Figure G-23. MOE 7 PC/PCINT x SENS x DENTI (BEG) Interaction

APPENDIX H

SIDE EXCURSION

Because of unexpected analysis results concenring the PC/PCINT effect, additional model runs were made involving PC/PCINT (B), SENS (E), and DENTI (G). Output data from the side excursion to the sensitivity experiment is presented in this appendix. Discussion of the side excursion is given in Chapter 3, paragraph 3-8.

Table H-1. Side Excursion of PC/PCINT and DENTI for SENS=20

B	MOE 1 G 0.000006	MOE 1 G 1.5	MOE 1 G 3.0	MOE 2 G 0.000006	MOE 2 G 1.5	MOE 2 G 3.0	MOE 3 G 0.000006	MOE 3 G 1.5	MOE 3 G 3.0
0.001	6	465	465	80	3,986	3,986	4	337	337
0.1	255	1,607	1,607	4,176	5,214	5,214	326	458	458
0.2	255	1,759	1,759	4,176	5,214	5,214	326	458	458
0.3	255	1,768	1,768	4,176	5,214	5,214	326	458	458
0.4	255	1,778	1,778	4,176	5,214	5,214	326	458	458
0.8	255	1,800	1,800	4,176	5,214	5,214	326	458	458

B	MOE 4			MOE 5			MOE 6		
0.001	4,677	8,594	8,594	3,610	3,924	3,924	7,569	6,685	6,685
0.2	8,833	9,848	9,848	3,902	4,027	4,027	7,054	6,534	6,534
0.1	8,833	9,848	9,848	3,902	4,027	4,027	7,054	6,534	6,534
0.3	8,833	9,848	9,848	3,902	4,027	4,027	7,054	6,534	6,534
0.4	8,833	9,848	9,848	3,902	4,027	4,027	7,054	6,534	6,534
0.8	8,883	9,848	9,848	3,902	4,027	4,027	7,054	6,534	6,534

B	MOE 7		
0.001	1,378	1,212	1,212
0.1	1,279	1,163	1,163
0.2	1,279	1,163	1,163
0.3	1,279	1,163	1,163
0.4	1,279	1,163	1,163
0.8	1,279	1,163	1,163

Table H-2. Side Excursion of PC/PCINT and DENTI for SENS=40

	MOE 1 G			MOE 2 G			MOE 3 G		
B	0.000006	1.5	3.0	0.000006	1.5	3.0	0.000006	1.5	3.0
0.001	11	900	900	287	5,289	5,289	13	461	461
0.1									
0.2	255	3,561	3,561	4,176	6,157	6,157	326	529	529
0.3									
0.4	255	3,561	3,561	4,176	6,157	6,157	326	529	529
0.8									

	MOE 4			MOE 5			MOE 6		
B	0.000006	1.5	3.0	0.000006	1.5	3.0	0.000006	1.5	3.0
0.001	4,884	9,925	9,925	3,617	4,029	4,029	7,569	6,535	6,535
0.1									
0.2	8,833	10,694	10,694	3,902	4,102	4,102	7,054	6,113	6,113
0.3									
0.4	8,833	10,694	10,694	3,902	4,102	4,102	7,054	6,113	6,113
0.8									

	MOE 7		
B	0.000006	1.5	3.0
0.001	1,378	1,163	1,163
0.1			
0.2	1,279	1,014	1,014
0.3			
0.4	1,279	1,014	1,014
0.8			